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WAR, FAMINE AND PESTILENCE

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THE melancholy tale of famine repeats itself with sinister regularity in the course of man's long struggle both with nature and his fellow man. Throughout recorded history, floods, drouths, earthquakes, frosts, blights and plagues of insects have shown their devastating power from time to time to cause famine and its accompanying pestilences. Furthermore, man himself, by his economic maladjustments, strifes and wars, creates additional conditions which also lead to want and hunger. But no matter how famine may be caused, pestilence, its faithful friend, stands always by, ready to add to the cauldron of misery a varied assortment of infectious agents which, in individuals or in multitudes, can destroy most quickly their devitalized and less-resisting victims.

Abraham Lincoln once said that God must love the poor because he makes so many of them. It might likewise be said that man must love disease because he makes so much of it. Although disease has always taxed the utmost powers of human ingenuity, human beings, nevertheless, continue to create new maladies almost as rapidly as they learn to conquer older ones. A host of man-made diseases—alcoholism, vitamin deficiencies, industrial disease, social strife, poverty, war—all testify to man's unwillingness to learn the costly lessons of the past. Is it any wonder, therefore, that man-made famines follow so frequently the recurrent cycles of depressions and of war?

The term famine is usually applied to the condition of a marked dearth of food; there are, of course, degrees of dearth, and individuals fortunate enough to possess some wealth can frequently get food or else flee from the famine area. This ability to buy food on the part of some, however, tends to increase the scarcity for others; in other words, the buying power of the few forces up the prices for the many, thus making the burden on the poor more severe. In Germany in World War I this sequence led to disaster and caused, in part, the final collapse. Due to governmental errors in the control of the limited food-supplies whereby farm prices were fixed while wages were not, illegal selling of food soon led to the development of the pernicious system of "schleich-handel," today's "black market." It has been estimated that near the close of the war from one quarter to one third of the Germans' food supply consisted of smuggled goods. But inasmuch as the poor, under such circumstances, are powerless either to buy enough food, due to steadily rising prices, or to escape from the area of famine, they constantly grow poorer. Soon fear and hunger become more urgent and panic hurries them along, first to spiritual and later to physical deterioration.

The paramount fact in famine, there-

fore, is poverty, which, if not relieved, leads inevitably to disaster. As Geddes Smith has aptly said, "There can be no doubt that the bitter bread of poverty is seasoned with disease and early death." For example, it is well known that the death rates from tuberculosis and pneumonia vary inversely with the economic state; and surveys made some years ago showed that the morbidity rates from pneumonia were twice as high in people on relief as in those with comfortable family incomes. The same trends also apply to tuberculosis (Smith). Walford has pointed out that nearly all the great epidemics of typhus have occurred during seasons of scarcity and want and that "whatever may have been the cause of the scarcity, it has been a common observation in many epidemics that the fever has raged among the poor in a degree proportionate to the privations they have endured. It was especially observable during the Irish potato famine: those persons who had been reduced by insufficient food were invariably attacked." It is apparent, therefore, that famine and poverty serve as faithful handmaidens to pestilence itself.

Great famines have played a dominant part in shaping many of the events of history and few countries have escaped their moulding influences. Two thousand years before the birth of Christ recurrent famines, due to failure of the Nile to flood, reduced the civilization of that time to the lowest levels of human degradation; since then fearful famines have occurred in India, Russia, England, Ireland, Europe, China and Egypt and it has been said (McKinnon) that during the first seventeen centuries of the Christian era famine occurred somewhere nearly every eight years, accompanied by pestilence almost every five.

In all these famines poverty, hunger and fear combined to liberate the evil forces manifested so frequently in murder, robbery, suicide and revolution. For example, in some of Egypt's early famines social strife quickly dominated the scene, and revolution led to counter-revolution as slaves turned on their masters and citizens organized to kill the slaves. Peasants refused to till the fields for fear of being murdered, thus adding to the dearth of food. In a famine portrayed in the second book of Kings cannibalism is described. In fact in all countries where famines have been unusually severe human flesh has been eaten, and not infrequently graves have been opened for their food. The Roman Empire suffered frequently, and in one famine thousands of desperate people are said to have drowned themselves in the Tiber because of the pangs of hunger. In England in the year following the battle of Hastings, William the Conqueror devastated the eastern coast so that "no hold might remain for any future invasion of the Danes. Harvest, cattle, the very implements of husbandry were so mercilessly destroyed that the famine which followed is said to have swept off more than a hundred thousand victims, and half a century later the land still lay bare of culture and deserted of men." Again in England some centuries later the devastation following the Black Death so reduced the normal supplies of labor that "harvests rotted on the ground and the fields were left untilled, not merely from scarcity of hands, but from the strife which now for the first time revealed itself between capital and labour." In Ireland, in the eighteenth century, depressions and attendant poverty led to "want and misery on every face . . . the roads spread with dead and dying bodies, mankind the color of the docks and nettles which they fed on . . . the universal scarcity was followed by fluxes and malignant fevers, which swept off multitudes of all sorts, so that whole villages were laid waste."

Of Russia in recent years Gantt says: "The famine of 1920–21 was probably by

far the worst in the history of Russia. Dogs, cats, horses, camels, rats, roots, berries, earth, dung, corpses were eaten, and the author knew of cases of human meat being sold in the market, and of people killing their sisters, brothers, parents and children for food. In Samara the insane asylum housed chiefly cannibals. Cities were sometimes reduced to one third or one half by famine and epidemics."

These tragic hungers, fearful as they were, seem merely "curtain raisers" to the world-wide drama unfolding in the total war which now affects all nations. To-day the specter of famine struts across the stage more boldly than in former wars, as to the forces which engender poverty and scarcity of food is added the impossibility of escape for many. Modern war attempts, by sinkings from beneath and on the sea and by bombs and fire from the sky, to bring stark famine to the enemy and thereby break his will to fight. In this grim struggle slight protection can be afforded women, children and non-combatants; in fact, if soldiers are to be fed, non-combatant populations, particularly those in conquered countries, must suffer most of all. Infectious disease, therefore, becomes much more than a problem of germ-transmission. It becomes, instead, more complicated, and its development is subject more and more to the determining influences of malnutrition which tend to deprive the body of the customary means of resisting infectious processes that are ordinarily well-borne. Moreover, famine usually is made worse by devitalizing fatigue as starving individuals strive as long as possible to secure the food essential for their survival. If, also, they must endure slavery while working for their captors, inevitably the time will come when famine and pestilence will take over where war leaves off. And when that time comes, again it can be truly said that "Grim, gaunt and loathsome, like the three fateful sisters of Greek mythology, war, famine and pestilence have decreed untimely deaths for the hosts of the earth. . . . A veritable trinity of evil, the three are as one scourge, equal in their devastating power and in their sinister universality" (Graves).

The constant association of this "evil trinity" is not surprising in view of wars' disruption of the normal modes of life. The assemblage in intimate relationships of large groups of young men, the manifold exposures to the elements and to one another with the resultant opportunities for the transmission of infectious agents from person to person, either directly or from increasingly concentrated air contamination, all furnish abundant opportunities for "herd infection." Moreover, the disorganizations of civilian life, excessive taxation and the loss of crops and commerce involve every one in the generalized confusion. Inevitably there follow scarcities of food supplies, physical hardships, exposure to fatigue and to unsanitary ways of living, all of which may tend to lessen resistance to infectious disease. It is because of these effects, therefore, that in the past as epidemics of typhus, cholera, typhoid fever and relapsing fever followed famine they earned the names of "famine fevers."

It is true that in many of the former wars the pestilences affected mainly the armies in the field, as seen, for example, in the epidemics of typhus and typhoid fever among Napoleon's troops on their retreat from Moscow. But more disastrous was their effect upon civilians as these soldiers spread disease both on the route from Russia and after their return home. Indeed Clark says that "the most serious human cost of war has been not losses in the field, nor even the losses from disease in the armies, but the losses from epidemics disseminated among the civil populations. It was the war epi-

demics and their sequelae, rather than direct military losses, that accounted for the deep prostration of Germany after the Thirty Years War."

Of all former wars this war (1618–48) affords perhaps the closest analogy to the present conflict. In it all Europe was a battlefield on which civilians suffered more than combatants as famine and pestilence took their heavy tolls. Prinzing, in fact, divided it quite simply into two main periods, the typhus period and the plague period. Major says that at the close of this long struggle,

> the picture of desolation, famine, disease, death, confusion and anarchy presented by Central Europe resembled the chaos which followed the downfall of the Roman Empire . . . in Germany the cities had become depopulated and fallen into decay; the countryside, with its cultivators dead, became a dreary desert. The churches were destroyed or empty, with their priests dead or dispersed. The schools and universities had disbanded, their teachers killed or scattered to the four winds. The libraries and museums, repositories of centuries of learning and culture, had been destroyed. Central Europe has no blacker page in its long history of travail and suffering. . . . It would be pleasant to record that some nuggets of pure gold had been drawn from the consuming fire of the Thirty Years War, but the search has been fruitless. The contemporary historians' writings record only a melancholy story of plunder, pillage and pestilence. Their pages are filled with accounts of pestilence, scenes of horror and death, epidemics sweeping the cities and countryside, unchecked by any medical discoveries, dying down only for lack of victims. . . . The effects . . . in Germany were felt for several generations. While the scientists of England, France, Holland and Italy were making the astonishing discoveries that mark the seventeenth century as a turning point in the history of science, depopulated and devastated Germany was rebuilding her destroyed cities, reclaiming her desert lands and trying to regain some vestiges of a civilization destroyed by thirty years of incessant warfare. The war had made a desert not only of their country but of their minds as well.

The description of this widespread chaos makes one wonder if indeed it is a preview of the coming years. The achievements of modern medicine seem almost futile when confronted with such devastation. Universal misery, famine and destitution can largely nullify all efforts to prevent dissemination of disease when, with water supplies polluted, with lice and rats breeding in the ruins of bombed cities, with scanty fuel rations, with clothing inadequate for cold winters and with gnawing hunger imminent, people gradually lose the incentives to observe the simplest rules of hygiene. When to these factors are added severe malnutrition and despair, the record of the Thirty Years War may once again become a familiar story in many European homes.

One of the tragedies of the present war lies in the fact that so many are now engaged throughout the world, and all with patriotic fervor, in tearing down those structures conceived and erected by some of the world's great minds in an effort to eliminate the disastrous consequences of infectious disease. The conquest of infection is a task in which all nations have had a share, and such names as Pasteur, Roux, Ehrlich, Behring, Koch, Metchnikoff, Jenner, Lister, Shiga, Kitasato, Smith and Ricketts illustrate the efforts of kindly men to conquer and control the ravaging pestilences of mankind. Because of them the science, immunology, arose, and through its influence in a few short years infectious disease has lost much of its terror. Of these, Churchill's tribute might be paraphrased, for never in the field of human endeavor was so much owed by so many to so few. Certainly within the past few decades more has been accomplished in the prevention and control of infectious disease than in all the centuries before. Such diseases as rabies, smallpox, typhoid fever, typhus, diphtheria, scarlet fever, plague and tetanus no longer call forth the dread once associated with their names. Improvements in the art of immunization based on procedures developed in the past half-century have made possible the protection of large populations, both in military and in civil life.

Resistance to infectious disease depends upon defensive mechanisms either inherited or acquired. To some diseases man is naturally immune, just as there are human diseases to which the lower animals are resistant. Under normal conditions many kinds of bacteria, viruses and animal parasites are unable to overcome these defensive mechanisms, but resistance to them, nevertheless, is always limited, and only slight environmental changes may, at times, disturb the delicate balance between susceptibility and resistance.

The phenomena of acquired resistance are perhaps better understood than are those of natural resistance, and they certainly are more relied upon in the handling of infectious disease. Upon them depend the powers of public health departments and of armies to operate confidently in preventing the spread of communicable disease. Although the basic facts of acquired resistance are so well known, details secured within recent years have helped to demonstrate further both the potentialities and limitations of this defensive mechanism. A brief consideration of one aspect of acquired resistance may serve to clarify to some extent its complex relationships to many latent infectious processes which in wartime may flare up into severe pestilences.

Bacterial infection, looked at from a general point of view, is in its beginning in most instances a local process; that is, the microorganisms, if they are to induce disease, must first penetrate the external barriers of the body and begin to multiply. If they are unable to grow in their new environment they soon succumb; if, on the other hand, they grow and spread, they may disseminate to vital areas where ultimately they may cause a lethal outcome. It is obvious, consequently, that upon the microbe's ability to grow depends its adverse effects; the question of microbic growth, therefore, occupies the foreground of the general problem of infection and resistance. In bacterial infection, Time plays a commanding role: It is as important in an incipient infection as it is in a beginning forest-fire; for obviously, if conditions can be so controlled that bacteria, after entering the body, are compelled to remain localized at or near their portal of entry, in tissues unfavorable for bacterial growth, many of the dangers of acute infection will be removed.

Within the past few years much progress has been made in the understanding of the process of bacterial growth in early infectious lesions. By the production in experimental animals of so-called "model infections" it has been possible to observe through the microscope what actually happens in an area of beginning infection and to demonstrate how the development of an infective lesion can be controlled. For example, it has been learned that bacterial growth in normal tissues differs markedly from the growth in immune ones. In the latter the initial microbic growth is sparse and more circumscribed, and the inflammatory reaction is intensified and more effective. This fact is now well known and has been amply demonstrated with several kinds of pathogenic microorganisms and in different species of animals. One example will be given here, chosen because the facts are so well attested and so easily revealed.

The normal rabbit is extremely susceptible to infection with the pneumococcus. This fact is of particular significance because it affords an opportunity to study the early lesions sequentially in an infection which almost invariably leads to a lethal ending. This type of infection resembles in some respects, therefore, and particularly in its ultimate effects, infection of the human being with a virulent strain of the plague bacillus. Indeed some strains of the pneumococcus are so virulent and can

grow so readily in the rabbit's tissues that as few as four microorganisms, if injected into the skin, will kill within two days.

From careful microscopical studies of this so-called pneumococcic dermal lesion we know that the microorganisms grow freely in the tissues near their point of entrance, spread widely and rapidly to the body as a whole, and kill the animal by an overwhelming blood-stream infection. This "model infection," therefore, combines the conditions of absolute susceptibility of the host and unusually effective parasitic adaptability of the pneumococci. And yet, by a very simple immunologic device, *viz.*, immunization with dead pneumococci or injection of specific anti-pneumococcal serum, the native susceptibility of the rabbit can be changed into such a high degree of resistance that hundreds of lethal doses of virulent pneumococci can be injected with impunity. Microscopical observation reveals the significant fact that the immediate immune reaction so affects the pneumococci as to stop their growth and spread through the contiguous tissues. Immune bodies specific for the pneumococci, cooperating with the phagocytes, achieve the objective of acquired resistance, thereby converting a state of complete susceptibility into one of high resistance.

Acquired resistance, therefore, whether it has been attained by artificial immunization or after recovery from an earlier infectious process, manifests itself primarily by an enhanced capacity to prevent the later development of infection of a similar type. This capacity, moreover, depends in large measure upon the effective action of specific antibodies. The nature of these antibodies has been for many years an unsolved problem because of doubt concerning their chemical composition. Within the past decade, however, this problem has been solved. Chemical investigations have revealed the fact that antibodies are molecules of a body-protein, globulin, which has been specifically modified during its synthesis by contact with antigen. The demonstration of this fact unquestionably marks one of the important mile-stones in the field of immunology and is to be compared in significance to the recent chemical discoveries of the carcinogenic hydrocarbons which have had such an important influence upon the study of cancer.

Proof of the chemical composition of antibodies having thus been finally accomplished, it soon became apparent that their continued production within the tissues depends upon the latter's ability to synthesize globulin. This synthesis, in turn, requires the adequate intake of proteins in the food; in other words, food-proteins with a full complement of amino acids are essential both for the fabrication of normal globulin and of antibody-globulin. Diet, therefore, assumes a more significant role in acquired resistance than has hitherto been realized. Carbohydrates, minerals, fats and vitamins, regardless of their importance in the bodily economy, can not replace amino acids essential for globulin production; in other words globulin can not be constructed without protein "building stones" any more than masons can build with mortar only but without an adequate supply of bricks.

These facts assume a larger significance now that proof has been established that prolonged severe protein-starvation leads progressively to the depletion of the body's protein reserves from which both normal globulin and antibody-globulin are formed. Experiments in progress show, moreover, that animals so depleted lose the capacity to produce antibodies as abundantly as do well-nourished animals. The capacity of a protein-depleted animal to form antibodies normally can be again restored, however, by the rebuilding of the body's

protein reserves through the addition to the low-protein diet of a mixture of amino acids.

The relationship of food-intake to antibody-production becomes increasingly important to-day, for in a time of total war the protective potentialities of acquired resistance tend to undergo deterioration. And upon this deterioration may depend the fate of nations when they approach the abyss of imminent catastrophe as incipient infections begin to gain in strength and vigor. Such augmentation of microbic virulence may arise not only because of better opportunities for germ-transmission but also because starvation and fatigue, by their devitalizing action, may decrease the power of acquired resistance to function effectively.

Several facts may be cited foreshadowing these sinister eventualities; some, indeed, have already been alluded to with respect to the wars and famines of the past. More recent, however, is the evidence indicating the major roles played by starvation and disease in the termination of World War I. Although the Nazis wish to believe that that conflict ended because of trickery by their foes, there is abundant evidence that the year 1918 revealed to Germany and to Europe the colossal power of famine and pestilence to dominate rulers, generals and councils of war. Although the present war has not as yet reproduced the widespread miseries of 1918, except in the captive countries, fragmentary reports are already filtering through that tuberculosis is once more on the increase in Germany and that throughout Europe typhus, typhoid fever, cholera and other scourges may not be far behind. These diseases may, for a time, be kept in check, but it will be no surprise if, as in World War I, malnutrition, poverty and pestilence once more find a common rendezvous. Armies have altered the map of Europe before only to find themselves powerless to escape from the relentless grasp of famine and pestilence. Napoleon captured Moscow, but, when lack of food forced him to retreat, typhus and enteric disease soon made the *grande armée* a pitiable mass of panic-stricken, starving, dying refugees.

It is now well known that during World War I the death rate from tuberculosis increased throughout Europe and that by 1918 it had doubled in Germany. The fact is all the more significant because this death rate up until 1914 had been dropping steadily throughout the world; by 1918, however, it had risen again in Europe to a point about 25 per cent. higher than in 1914.

In attempting to ascertain the causes of this formidable rise the possibility of housing shortages and the resultant overcrowding came to mind, but observers soon pointed out that the rise in the mortality rate had preceded the housing shortage. Attention then was centered on the shortage of food, particularly fats and proteins. Furthermore, in Denmark the death rate from tuberculosis, although rising early in the war, dropped sharply in 1918. The probable explanation is that, as the food blockade in 1917 became more effective, the elimination of food exports forced the Danes to consume their own vast supply of dairy products. Moreover, the tuberculosis death rate continued to decline after the war, although Denmark had a serious housing shortage at that time.

In the present conflict, as in World War I, the slogan "Food Will Win the War" still plays an important and perhaps a dominant part in military strategy. Morale, the objective of all propaganda, may be sustained for months or even years by shrewd suppressions and distortions of the news, but no morale can be nourished indefinitely when suckled on the withered breast of hopeless and devitalizing hunger. Starvation will lead in time to lowered morale as

families sicken and die from infections which could be well tolerated in normal times. And always in the background lurks the danger that, as infectious agents pass more quickly from person to person under these conditions of decreased resistance, the possible exaltation of microbic virulence or the increasing concentrations of infective agents may lead eventually to the setting-off of fearful epidemics. No one knows just how these world-wide epidemics start, but we know from World War I what happened when influenza, typhus and cholera swept over large parts of the world. In the fourteenth century the Black Death which caused the deaths of about one half of the peoples of Europe followed, according to one suggestion, a fearful famine in northern China.

During the first World War famine brought into prominence a form of malnutrition whose importance had hitherto been largely underestimated. As starving peoples throughout Europe were forced to subsist on foods of low protein values, particularly potatoes, turnips, leafy plants and salty soups derived therefrom, large numbers of them, especially when performing hard labor, became dropsical. Furthermore, physicians reported that many of these patients manifested a markedly increased susceptibility to infections of various sorts. This condition had long been known under a variety of names, the most common being war edema. Observers looked vainly for the cause; although many suspected that it had a nutritional basis, attention centered largely around the idea that it was due to a vitamin inadequacy. Not until near the end of the war was the real cause determined; in 1918 two American physiologists, Miss Kohman and Miss Denton, demonstrated conclusively that the edema was due essentially to a deficiency of protein in the diet. When rats were fed on a diet low in protein but with adequate amounts of carbohydrate, fats, vitamins and salts, the edema appeared; its elimination was accomplished solely by the addition to the diet of a sufficient amount of protein (casein). As Dr. A. J. Carlson remarked at the end of the war: "After observing and studying war edema throughout Eastern Europe I returned to find that the cause had been discovered in my own laboratory." Since then these experiments have been abundantly confirmed and we know now that the edema is due to the lowered protein content of the blood, the consequence of a prolonged low protein diet. When the protein levels of the blood fall below a certain value, referred to as the "edema level," fluids tend to accumulate in the tissues because the lowered osmotic pressure of the blood can no longer prevent this transudation.

It is not surprising that in these states of hypoproteinemia there should be a lowered resistance to infectious agents because of an inability to synthesize antibody-globulin as effectively as in normal times.

The gradual depletion of the supplies of protein-rich foods in Europe under the circumstances of modern war seems almost inevitable. Although reliable information is not available, there can be but little question that the shortage of fodder must have led already to serious restrictions in the production of meat animals and of milk and dairy products. A gradual diminution in the supplies of fish, fowl, meat, cheese and eggs will lead necessarily to greater reliance upon vegetables, particularly potatoes (which contain only two per cent. protein) and to other vegetables of lower protein values. This war has been so planned and executed thus far by Germany that the first to suffer are the captive nations whose food resources have been "levied" and transported to Germany. There can be but little doubt, therefore, that starvation will reap its biggest harvest in

these conquered countries. Reports from Greece already tell of thousands dying from starvation, particularly infants and young children who can get but little if any milk, and similar events are doubtless happening elsewhere throughout conquered Europe. However, the fact remains, so far as Germany is concerned, that food and livestock once confiscated can not be levied upon again with equal profit. The gradual deterioration of the food supply throughout all Europe can lead but in one direction; and Europe is now in its fourth war winter. Furthermore, the time may not be far away when Germany will no longer hold these countries from which so much food is now confiscated. When that time comes, the real effects of famine inside Germany may quickly become more apparent.

Continued emphasis upon the importance of acquired resistance seems to be particularly warranted in the present war because infectious disease treats all alike. No longer is infection's harm restricted primarily to the fighting troops; the workers on the farms and in the factories are of increasing value to the military effort and their health becomes of prime importance. If, therefore, they succumb to infectious agents because of privation, cold, fatigue and hunger, the war effort will inevitably deteriorate. Such infections do not mean necessarily those commonly looked upon as war-time pestilences, but rather the so-called minor infections so commonly taken more or less lightly. Thus, "colds," bronchitis, mild pneumonias, diarrheas, pharyngitis, wound infections and the childhood diseases—measles, whooping cough, scarlet fever and diphtheria—which usually are not characterized by high death rates may become definitely more menacing. For example, Prinzing, in commenting on the effects of the siege of Paris of 1870, says:

Insufficient nourishment is seldom the direct cause of death; on the other hand, it frequently so weakens people that they are much more subject to sickness, or, if they have already contracted some disease, they are much more likely to die, or, if they recover, to convalesce slowly. Thus Vacher states that typhoid fever, which usually results fatally in one out of four cases, during the siege of Paris carried away no less than forty per cent. of those who contracted it; tuberculosis, he says, often acquired an acute form and caused death within a few weeks. Little children present slight resistance to famine.

The implications of these facts in severe starvation are obvious. Although the depletion of the body's protein reserves is gradual and may not take on alarming proportions for months or even years, nevertheless it will develop insidiously when one is compelled to live energetically and to work laboriously under conditions of exposure to fatigue and cold on an inadequate protein-intake. Furthermore, due to the fact that the protein foods are the most expensive kinds, and even if available, can not be purchased by people in countries whose currencies have been debased, poverty once more dominates the famine-picture, particularly in the occupied countries of Europe. No doubt the Germans entered this war with larger food reserves than in 1914, but it should be recalled that for many years their policy of guns before butter has had some effect upon the overall nutritional picture of the German civilians. Only the future can reveal the long-time effects of such food-restriction, but it is apparent that the ideas of "blitzkrieg" and "vielejähinge krieg" are diametrically opposed. From now on the difficulties in replacing farm machinery will become greater, and with more and more persons thrown into the combat lines in Russia and elsewhere, the ability of old men, women, children, cripples and prisoners of war to grow the food will become more difficult. And even when produced the increasing strain on transportation is bound to tell in a protracted war.

Out of these famines, wars and pesti-

lences it is to be hoped that at least some human progress may have been achieved. Although too frequently only psychopathic manifestations dominate the historical scene, there is no doubt but that in some instances human welfare has been advanced. Although the Black Death killed its millions, in England it was followed by the Peasants' Revolt, which accelerated the break-up of the large estates and the development of industry by the enlarging middle class. In France the many famines caused too often by the excessive taxes imposed by wasteful kings and courts had their eventual aftermath in the Revolution of 1789. Ireland, too, made her general contribution to world-wide progress when the potato famine of 1846 compelled starving millions to emigrate to America. Thus by an irony of fate, America, in compensation for her earlier gift to Erin of the lowly potato, was later repaid by the Irish in person.

Less obvious are the effects of the pestilences when looked at from to-day's point of view. We have seen that in World War I Germany found that empty stomachs do not win wars. This lesson does not seem to have been well learned and events now unfolding may reveal again that the Germans, by depending too much on psychological warfare and blitzkrieg, may have overlooked some important lessons of physiology and pathology. For although it is true that he who lives by the sword may perish by the sword, it is truer still that he who lives by the sword may also perish by the famine and the pestilence.

HEALTH CONDITIONS IN POST-WAR EUROPE

If, in the midst of urgent war effort, justification is needed for the present publication, it is to be found in the fact that during the three years following the last war more individuals died from famine and preventable diseases than were killed in the war itself. This is the more impressive in that the death rate is no measure of the suffering and permanent impairment of health involved. The enormous loss of life was certainly due in part to the existing conditions, many of which were unavoidable, but was also attributable, in a much greater degree, to delay, chaos and the inadequacy of such early relief measures as were undertaken. For over a year after the signing of the armistice, relief work was organized only on the relatively fragmentary scale possible for the limited resources of voluntary bodies. Moreover, the absence of any central coordinating machinery caused serious overlapping, omissions and delay in the acquisition and transport of relief materials and personnel. Though from the beginning the problem was clearly far beyond the financial or administrative scope of private organizations, no central coordinating body was ever created, and more than a year elapsed before government contributions became available on any extensive scale. During this time malnutrition and famine were widespread and steadily increasing, whilst epidemic diseases raged unchecked.

It is only by the creation of a machine ready for immediate operation on the conclusion of hostilities that a similar but more terrible tragedy can be averted. Our obligations to the peoples of occupied countries alone make urgent action a responsibility which we can only properly discharge by careful thought and adequate preparations at the present time. The problems to be considered are many and difficult, but on their wise and rapid solution will depend the lives and health of millions, and the physique and welfare of a generation to come.

At present it is exceedingly difficult to visualize the general reconstruction that will be required in post-war Europe in the spheres of politics, economics and administration, all of which must necessarily be shaped by developments in Europe during the war and after. Medical problems are unlikely to vary in their character with the course of hostilities, and can, even now, be foretold with a reasonable degree of accuracy. Already malnutrition, and in some cases famine, with such resulting diseases as tuberculosis, are widespread over large areas of Europe, particularly Greece and Spain. Typhus fever is now epidemic in most of Eastern and much of Central Europe, as well as in Spain and North Africa. Malaria, too, is increasing. Unless these scourges are quickly combated they will become progressively more extensive as the war goes on, taking their toll of lives and health, including those of the young upon whom depends the future of humanity. As living conditions deteriorate, other diseases will inevitably be added to this group, and the growing shortage of medical personnel and supplies will make it less and less possible for many Governments to take the necessary steps for their prevention and eradication.—*From the foreword, "Medical Relief in Europe,"* by *Melville D. Mackenzie, M.D., The Royal Institute of International Affairs,* London.

PROBLEM OF THE EXPANDING UNIVERSE[1]

By Dr. EDWIN HUBBLE
MOUNT WILSON OBSERVATORY

I PROPOSE to discuss the problem of the expanding universe from the observational point of view. The fact that such a venture is permissible is emphatic evidence that empirical research has definitely entered the field of cosmology. The exploration of space has swept outward in successive waves, first through the system of the planets, then through the steller system and, finally, into the realm of the nebulae. To-day we study a region of space so vast and so homogeneous that it may well be a fair sample of the universe. At any rate, we are justified in adopting the assumption as a working hypothesis and attempting to infer the nature of the universe from the observed characteristics of the sample. One phase of this ambitious project is the observational test of the current theory of the expanding universes of general relativity.

I will briefly describe the observable region of space as revealed by preliminary reconnaissance with large telescope, then sketch the theory in outline, and finally discuss the recent more accurate observations that were designed to clarify and to test the theory.

The Observable Region

The sun is a star, one of several thousand million stars which together form the stellar system. This system is a great swarm of stars isolated in space. It drifts through the universe as a swarm of bees drifts through the summer air. From our position near the sun we look out through the swarm of stars past the borders, into the universe beyond.

Until recently those outer regions lay in the realm of speculation. To-day we explore them with confidence. They are empty for the most part, vast stretches of empty space. But here and there, separated by immense intervals, we find other stellar systems, comparable with our own. We find them thinly scattered through space out as far as telescopes can reach.

They are so distant that in general they appear as small faint clouds mingled among the stars, and many of them were long known by the name "nebulae." Their identification as great stellar systems, the true inhabitants of the universe, was a recent achievement of great telescopes.

On photographs made with such instruments, these nebulae, these stellar systems, appear in many forms. Nevertheless, they fall naturally into an ordered sequence ranging from compact globular masses through flattening ellipsoids into a line of unwinding spirals. The array exhibits the progressive development of a single basic pattern, and is known as the sequence of classification. It may represent the life history of stellar systems. At any rate, it emphasizes the common features of bodies which belong to a single family.

Consistent with this interpretation is the fact that these stellar systems, regardless of their structural forms, are all of the same general order of intrinsic luminosity (that is, of candlepower). They average about 100 million suns, and most of them fall within the narrow range from one-half to twice this

[1] Twentieth annual Sigma Xi Lecture, presented in association with the American Association for the Advancement of Science, Dallas, December 30, 1941.

average value. Giants and dwarfs are known, 10 to 20 times brighter or fainter than the average, but their numbers appear to be relatively small. This conclusion is definitely established in the case of giants, which can be readily observed throughout an immense volume of space, but it is still speculative in the case of dwarfs which can be studied only in our immediate vicinity.

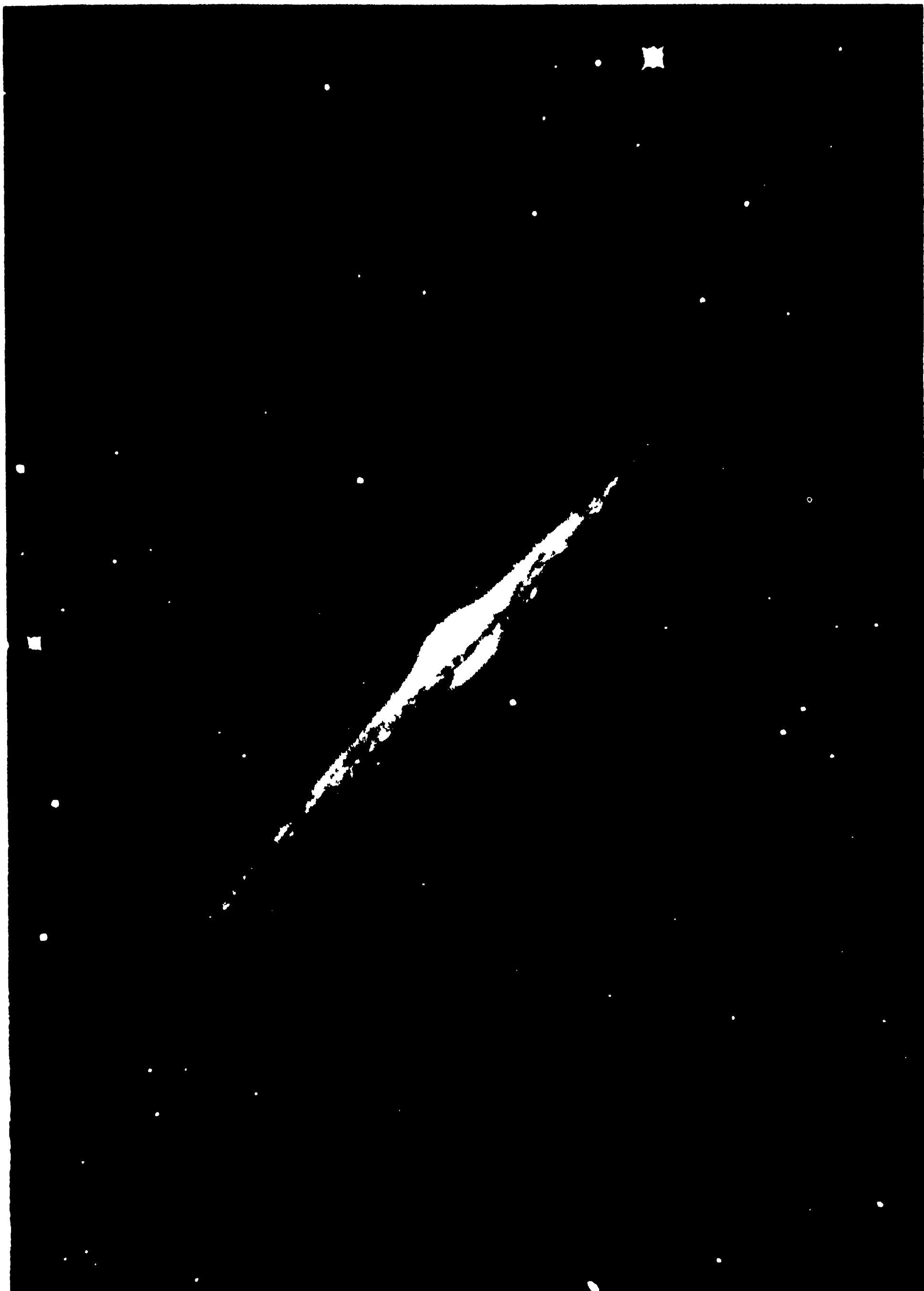
The limited range in luminosity is important because it offers a convenient measure of distance. As a first approximation, we may assume that the nebulae are all equally luminous, and, consequently, that their apparent faintness indicates their distances. The procedure is not reliable in the case of a single object because the particular nebula might happen to be a giant or a dwarf rather than a normal stellar system. But for statistical purposes, where large numbers of nebulae are involved, the relatively few giants and dwarfs should average out and the mean distances of large groups may be accurately determined. It is by this method that the more remote regions of space, near the limits of the telescope, may be explored with confidence.

Throughout the observable region we find the nebulae scattered singly, in pairs and in groups up to great compact clusters or even clouds. The small-scale distribution is irregular, and is dominated by a tendency towards clustering. Yet when larger and larger volumes of space are compared, the minor irregularities tend to average out, and the samples grow more and more uniform. If the observable region were divided into a hundred or even a thousand equal parts, the contents would probably be nearly identical. Therefore, the large-scale distribution of nebulae is said to be uniform; the observable region is homogeneous, very much the same everywhere and in all directions.

We may now present a rough sketch of our sample of the universe. The faintest nebulae that can be detected with the largest telescope in operation (the 100-inch reflector on Mount Wilson) are about two million times fainter than the faintest star that can be seen with the unaided eye. Since we know the average candle power of these nebulae, we can estimate their average distance—500 million light-years. A sphere with this radius defines the observable region of space. Throughout the sphere are scattered about 100 million nebulae, at various stages of their evolutional development. These nebulae average about 100 million times brighter than the sun and several thousand million times more massive. Our own stellar system is a giant nebula, and is presumably a well-developed, open spiral. The nebulae are found, as has been said, singly, in groups and in clusters but, on the grand scale, these local irregularities average out and the observable region as a whole is approximately homogeneous. The average interval between neighboring nebulae is about two million light-years, and the internebular space is sensibly transparent.

The Law of Red Shifts

Another general characteristic of the observable region has been found in the law of red shifts, sometimes called the velocity-distance relation. This feature introduces the subject of spectrum analysis. You are doubtless familiar with the fact that in general light from any source is a composite of many individual colors or wavelengths. When the composite beam passes through a glass prism or other suitable device, the individual colors are separated out in an ordered rainbow sequence known as a spectrum. The prism bends the light according to the wavelength. The deflections are least for the long waves of the red and are greatest for the short waves of the violet. Hence position in the spectrum indicates



A SPIRAL NEBULA SEEN EDGE ON

THIS STELLAR SYSTEM, NGC 4565, IS SO DISTANT THAT NONE OF THE STARS CAN BE SEEN INDIVIDUALLY.

the wavelength of the light falling at any particular place in the sequence.

Incandescent solids, and certain other sources, radiate light of all possible wavelengths, and their spectra are continuous. Incandescent gases, however, radiate only certain particular wavelengths, and their spectra, called emission spectra, consist of various isolated colors separated by blank spaces. The patterns are well known; hence gases in a distant light source can be identified by their spectra.

The sun presents a third kind of spectrum known as an absorption spectrum. The main body of the sun furnishes a continuous spectrum. The heavy atmosphere surrounding the main body is gaseous and would normally exhibit an emission spectrum. Actually, the atmosphere, because it is cooler than the main body, absorbs from the continuous background those colors it would otherwise emit. Therefore the solar spectrum is a continuous spectrum on which is superposed a pattern of dark gaps or lines. These dark lines identify the gases in the solar atmosphere and indicate the physical conditions under which they exist.

The nebulae are stellar systems and their spectra resemble that of the sun. Dark lines due to calcium, hydrogen, iron and other elements in the atmospheres of the component stars are identified with complete confidence. In the case of the nearer nebulae, these lines are close to their normal positions as determined in the laboratory or in the sun. In general, however, accurate measurements disclose slight displacements either to the red or to the violet side of the exact normal positions.

Such small displacements are familiar features in the spectra of stars and are known to be introduced by rapid motion in the line of sight. If a star is rapidly approaching the observer, the light waves are crowded together and shortened, and all the spectral lines appear slightly to the violet side of their normal positions. Conversely, rapid recession of a star drags out and lengthens the light waves, and the spectral lines are seen to the red of their normal positions.

The amounts of these displacements (they are called Doppler shifts) indicate the velocities of the stars in the line of sight. If the wavelengths are altered by a certain fraction of the normal wave-

THE SPECTRUM OF THE SPIRAL NEBULA, MESSIER 81

THE SOLAR TYPE SPECTRUM OF THE SPIRAL NEBULA MESSIER 81 IS TYPICAL OF EXTRAGALACTIC NEBULAE IN GENERAL. THE SPECTROGRAM IS REPRODUCED IN NEGATIVE FORM IN ORDER TO SHOW FAINT DETAILS. THE SPECTRUM OF THE NEBULA IS THE BROAD DARK STREAK IN THE CENTER THAT IS CROSSED VERTICALLY BY SOME FAINT LIGHTER LINES, THE ABSORPTION LINES PRODUCED BY THE NEBULA. ABOVE AND BELOW THE SPECTRUM OF THE NEBULA ARE COMPARISON LINES FROM AN ARTIFICIAL SOURCE. THE MOST CONSPICUOUS FEATURE IS THE PAIR OF ABSORPTION LINES (H AND K) DUE TO CALCIUM, WHICH ARE SEEN NEAR THE COMPARISON LINE 3964. MANY FAINT ABSORPTION LINES, DUE TO IRON AND A FEW DUE TO HYDROGEN AND CALCIUM, CAN ALSO BE SEEN, AS WELL AS THE EMISSION LINE 3727, AT THE EXTREME RIGHT. THE LINES ARE SLIGHTLY TILTED BY THE ROTATION OF THE SPIRAL.

lengths, the star is moving at a velocity which is that same fraction of the velocity of light. In this way it has been found that the stars are drifting about at average speeds of 10 to 30 miles per second, and, indeed, that the stellar system, our own nebula, is rotating about its center at the majestic rate of one revolution in perhaps 200 million years.

Similarly, the nebulae are found to be drifting about in space at average speeds of the order of 150 miles per second. Such speeds, of course, are minute fractions of the velocity of light and the corresponding Doppler shifts, which may be either to the violet or to the red, are barely perceptible.

But the spectra of distant nebulae show another effect as conspicuous as it is remarkable. The dark absorption lines are found far to the red of their normal positions. Superposed on the small red or violet shifts representing individual motions is a systematic shift to the red which increases directly with the distances of the nebulae observed. If one nebula is twice as far away as another, the red shift will be twice as large; if n times as far away, the red shift will be n times as large. This relation is known as the law of red shifts, and it appears to be a quite general feature of the observable region of space.

If these systematic red shifts are interpreted as the familiar Doppler shifts, it follows that the nebulae are receding from us in all directions at velocities that increase directly with the momentary distances. The rate of increase is about 100 miles per second per million light years of distance, and the observations have been carried out to nearly 250 million light years where the red shifts correspond to velocities of recession of nearly 25,000 miles per second, or one seventh the velocity of light.

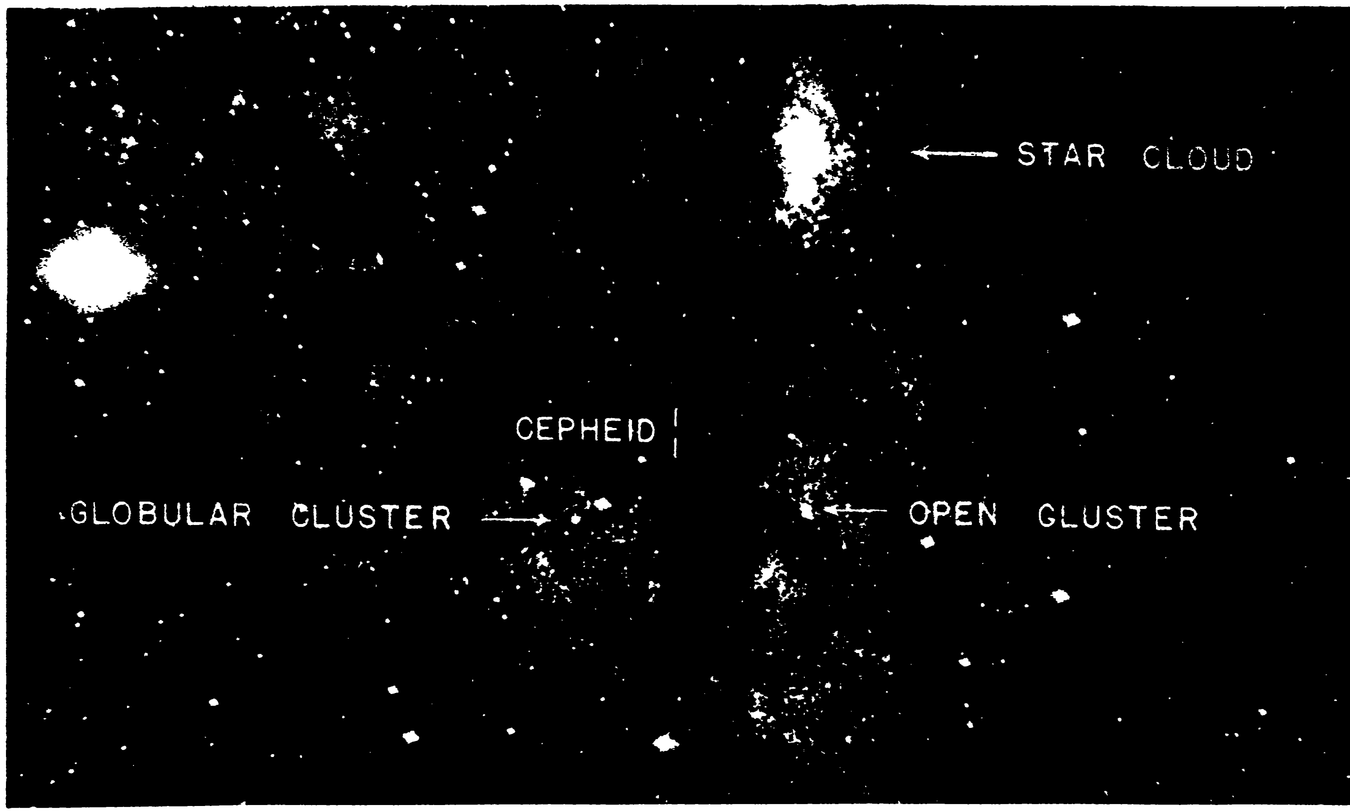
On this interpretation we could account for the present distribution of nebulae by the assumption that all the nebulae were once jammed together in a very small volume of space. Then, at a certain instant, some 1,800 million years ago, the jam exploded, the nebulae rushed outward in all directions with all possible velocities, and have maintained these velocities to the present day. Thus the nebulae have now receded to various distances, depending upon their initial velocities, and our observations necessarily uncover the law of red shifts.

This pattern of history seems so remarkable that some observers view it with pardonable reserve, and try to imagine alternative explanations for the law of red shifts. Up to the present, they have failed. Other ways are known by which red shifts might be produced, but all of them introduce additional effects that should be conspicuous and actually are not found. Red shifts represent Doppler effects, physical recession of the nebulae or the action of some hitherto unrecognized principle in nature.

Cosmological Theory

The preliminary sketch of the observable region was completed about ten years ago. It was not necessarily a finished picture, but it furnished a rough framework within which precise, detailed investigations could be planned with a proper understanding of their relation to the general scheme. Such new investigations, of course, were guided when practical by current theory. Let me explain the significance of this procedure.

Mathematicians deal with possible worlds, with an infinite number of logically consistent systems. Observers explore the one particular world we inhabit. Between the two stands the theorist. He studies possible worlds but only those which are compatible with the information furnished by observers. In other words, theory attempts to segregate the minimum number of possible worlds which must include the actual world we inhabit. Then the observer,



THE NEAREST SPIRAL NEBULA

THE PICTURE SHOWS AN OUTER REGION OF THE GREAT SPIRAL IN ANDROMEDA, PHOTOGRAPHED WITH THE 100-INCH REFLECTOR. THE BRIGHTER STARS CAN BE SEEN INDIVIDUALLY, AND AMONG THEM VARIOUS TYPES CAN BE RECOGNIZED WHICH ARE WELL-KNOWN IN OUR OWN STELLAR SYSTEM. THE APPARENT FAINTNESS OF THESE STARS INDICATES THAT THE DISTANCE OF THE SPIRAL IS ABOUT 700,000 LIGHT YEARS.

with new factual information, attempts to reduce the list still further. And so it goes—observation and theory advancing together toward the common goal of science, knowledge of the structure and behavior of the physical universe.

The relation is evident in the history of cosmology. The study at first was pure speculation. But the exploration of space moved outward until finally a vast region, possibly a fair sample of the universe, was opened for inspection. Then theory was revitalized; it now had a sure base from which to venture forth.

Current theory starts with two fundamental principles, general relativity and the cosmological principle. General relativity states that the geometry of space is determined by the contents of space, and formulates the nature of the relation. Crudely put, the principle states that space is curved in the vicinity of matter, and that the amount of curvature depends upon the amount of matter. Because of the irregular distribution of matter in our world, the small-scale structure of space is highly complex. However, if the universe is sufficiently homogeneous on the large scale, we may adopt a general curvature for the universe or for the observable region as a whole, just as we speak of the general curvature of the earth's surface, disregarding the mountains and ocean basins. The nature of the spatial curvature, whether it is positive or negative, and the numerical value, is a subject for empirical investigation.

The second, or cosmological, principle is a pure assumption—the very simple postulate that, on the grand scale, the universe will appear much the same from whatever position it may be explored. In other words, there is no favored position in the universe, no center, no boundaries. If we, on the earth, see the universe expanding in all directions, then any other observer, no matter where he is located, will also see the universe expanding in the same manner. The postulate, it may be added, implies that, on the grand scale, the universe is homogeneous and isotropic—very much the same everywhere and in all directions.

Modern cosmological theory attempts to describe the types of universes that are compatible with the two principles, general relativity and the cosmological principle. Profound analysis of the problem leads to the following conclusions. Such universes are unstable. They might be momentarily in equilibrium, but the slightest internal disturbance would destroy the balance, and disturbances must occur. Therefore these possible worlds are not stationary. They are in general either contracting or expanding, although theory in its present form does not indicate either the direction of change or the rate of change. At this point, the theorist turned to the reports of the observers. The empirical law of red shifts was accepted as visible evidence that the universe is expanding in a particular manner and at a known rate. Thus arose the conception of homogeneous expanding universes of general relativity.

In such universes the spatial curvature is steadily diminishing as the expansion progresses. Furthermore, the nature of the expansion is such that gravitational assemblages maintain their identities. In other words, material bodies or groups and clusters of nebulae do not themselves expand but maintain their permanent dimensions as their neighbors recede from them in all directions.

Several types of expanding universes are possible, and some of them can be further specified by the nature of the curvature, whether it is positive or negative. In fact, the particular universe we inhabit could be identified if we had sufficiently precise information on three measurable quantities, namely, the rate of expansion, the mean density of matter

in space and the spatial curvature at the present epoch. Recent empirical investigations have been directed toward these problems, and the results will be briefly described in the remaining section of this discussion.

Comparison of Theory and Observations

We may begin with two results which are thoroughly consistent with the theory. The first result concerns the assumption of homogeneity; the second, the conclusion that groups maintain their dimensions as the universe expands.

The distribution of nebulae has been studied in two ways. The first information came from sampling surveys at Mount Wilson and at the Lick Observatory. Small areas, systematically scattered over the sky, were studied with large telescopes. Thus the nebulae that were counted lay in narrow cones penetrating to vast distances. These surveys established large-scale homogeneity over the three quarters of the sky that could be studied from the northern latitudes of the observatories involved.

Later, the Harvard College Observatory, with the help of its southern station, has furnished counts of nebulae extending over large areas but made with telescopes of moderate size. In other words, the nebulae are scattered through wide cones penetrating to moderate distances. Shapley, in his reports, has stressed or perhaps overly stressed, the familiar, small-scale irregularities of distribution, but analysis of such published data as are adequately calibrated agrees with the earlier conclusion. In fact, the mean results from the two quite different methods of study are sensibly the same. This fact re-emphasizes the large-scale homogeneity of the observable region.

The second result is derived from a study of the Local Group. Our own stellar system is one of a dozen nebulae which form a loose group more or less isolated in the general field. These neighboring systems furnished the first clues to the nature of the nebulae and the scale of internebular distances. They are so near that their brightest stars could be recognized and compared with similar stars in our own system. Radial velocities of the members of the Local Group, listed in Table I, suggest that the law of red shifts probably does not operate within the group. This conclusion is positive evidence supporting the validity of the theory. If the universe is expanding, the group maintains its dimensions as the theory requires.

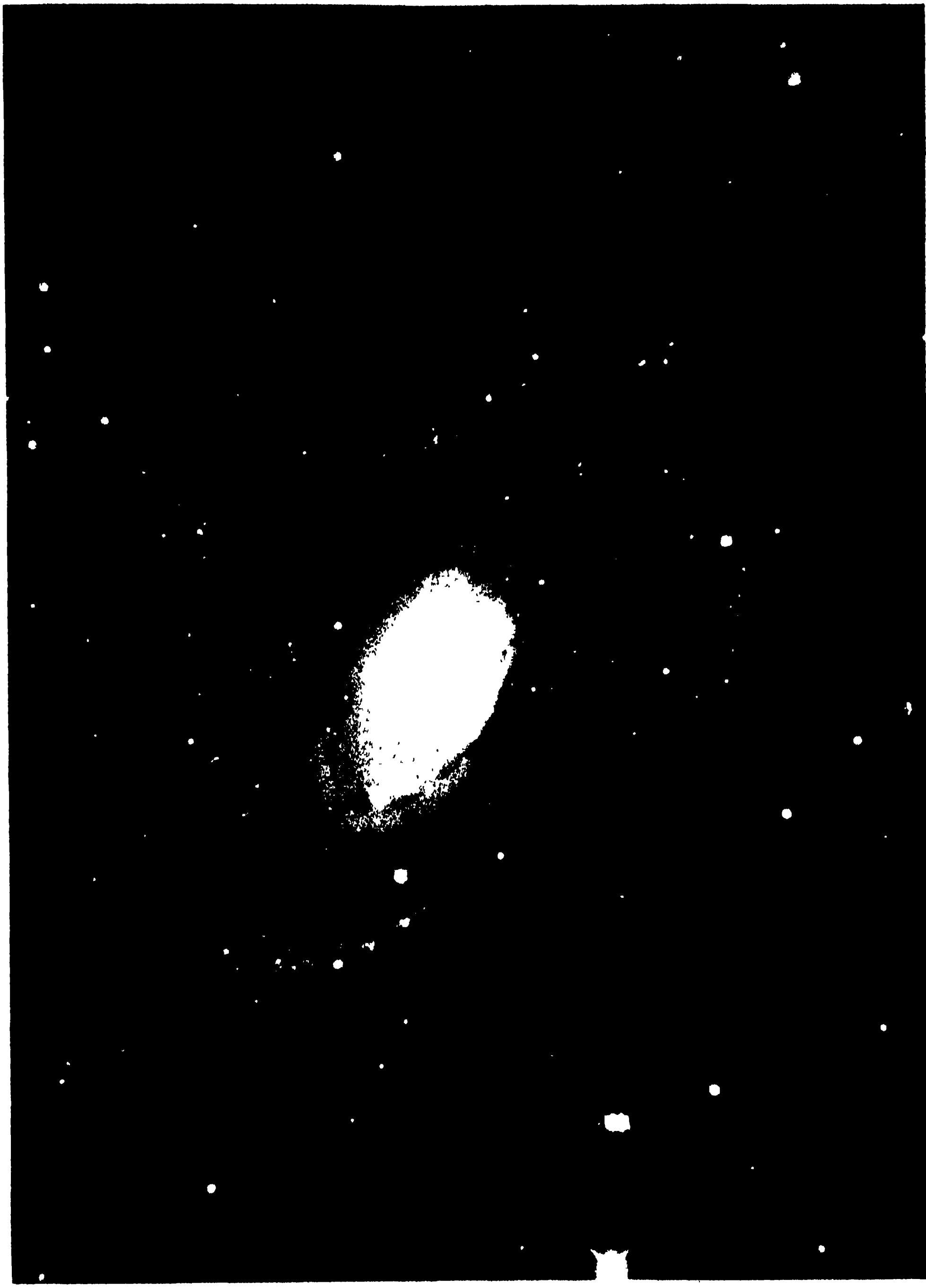
TABLE I

Radial Velocities in the Local Group*

Known members	Observed velocity	Distance in million light years	Expected red shift	Velocity with red shift removed
L M C	+ 45	0.085	+ 13	+ 32
S M C	+ 13	0.095	+ 16	− 3
M 31	− 130	0.7	+ 110	− 240
M 33	− 140	0.7	+ 115	− 265
NGC 6822	+ 20	0.5	+ 85	− 60
IC 1316	− 370	1.3	+ 210	− 580
Fornax	− 40	0.6	+ 100	− 140
Probable members				
NGC 6946	+ 90	1.6	+ 265	− 175
NGC 1569	+ 60	2.3	+ 370	− 310
IC 342	+ 30	2.3	+ 370	− 340

* The observed velocities (second column) represent a more reasonable distribution than the velocities corrected for red shifts (fifth column). The latter are all large and negative with the exception of the first two, for which the corrections are insignificant. This fact suggests that the law of red shifts does not operate within the Local Group.

The remainder of the recently accumulated information is not favorable to the theory. It is so damaging, in fact, that the theory, in its present form, can be saved only by assuming that the observational results include hidden systematic errors. The latter possibility will naturally persist until the investigations can be repeated and improved. Nevertheless, a careful reexamination of the data now available suggests no adequate explanation of the discrepancies.



THE SPIRAL NEBULA, MESSIER 81

THIS STELLAR SYSTEM IS AT A DISTANCE OF ABOUT THREE TIMES THAT OF THE GREAT SPIRAL IN ANDROMEDA, AND ONLY A FEW OF THE BRIGHTER STARS CAN BE SEEN INDIVIDUALLY.

The Interpretation of Red Shifts

The investigations were designed to determine whether or not red shifts represent actual recession. In principle, the problem can be solved; a rapidly receding light source appears fainter than a similar but stationary source at the same momentary distance. The explanation of this well-known effect is quite simple when the beam of light is pictured as a stream of discrete quanta. Rapid recession thins out the stream of quanta; hence fewer quanta reach the eye per second, and the intensity, or rate of impact, is necessarily reduced. Quantitatively, the normal brightness is reduced by a fraction which is merely the velocity of recession divided by the velocity of light—in other words, the red shift expressed as a fraction of the normal wavelengths of the light in question. Recession at one tenth the velocity of light reduces the apparent brightness by 10 per cent.; at one quarter the velocity of light, by 25 per cent.

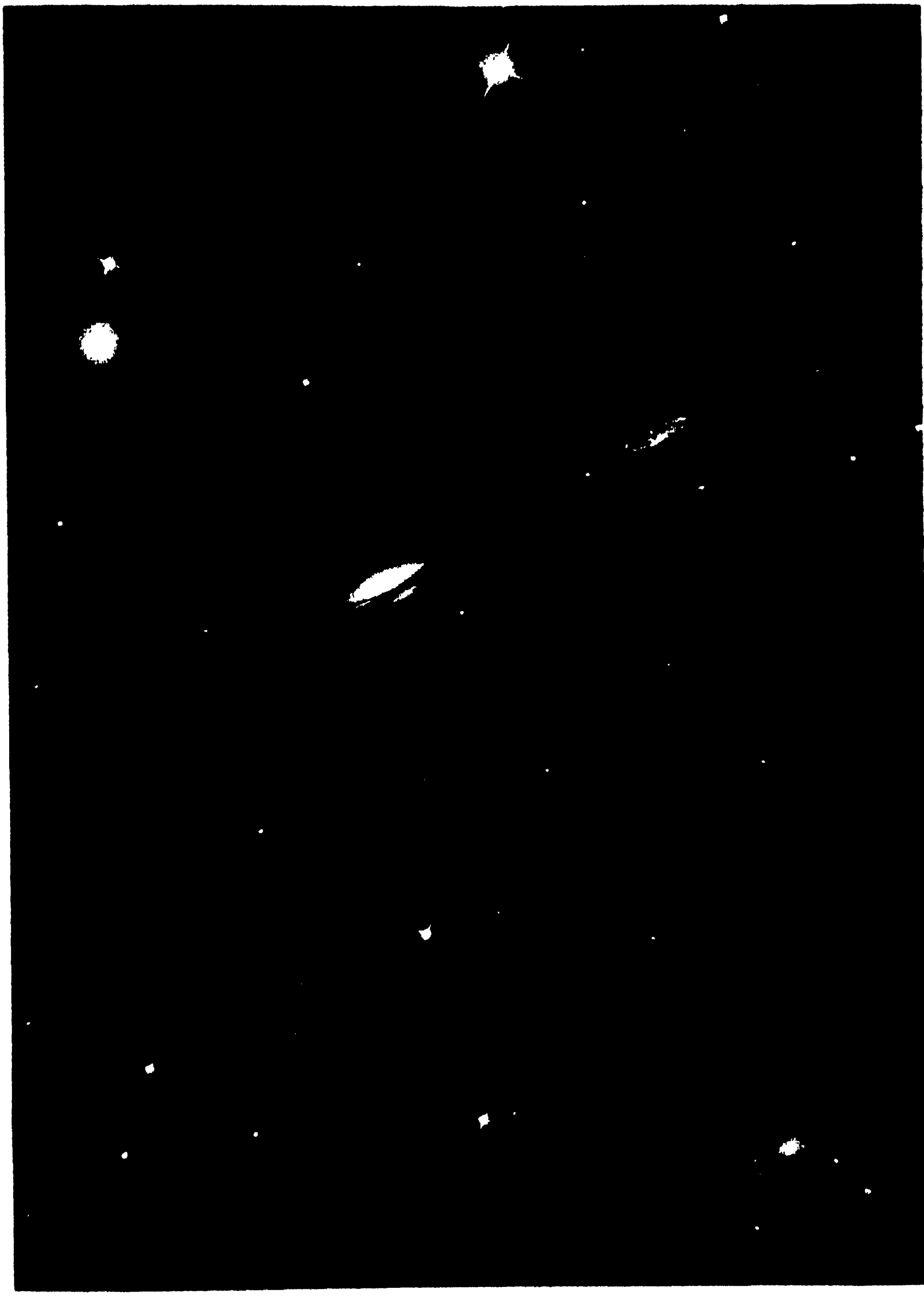
For velocities of a few miles or a few hundred miles per second, the dimming factor is negligible. But for the extremely distant nebulae, where the apparent recessions reach tens of thousands of miles per second, the effects are large enough to be readily observed and measured. Hence, if we knew the distances of nebulae quite accurately we could measure their apparent faintness and tell at once whether or not they are receding at the rates indicated by the red shifts.

Unfortunately, the problem is not so simple. The only general criterion of great distances is the very apparent faintness of the nebulae which we wish to test. Therefore, the proposed test involves a vicious circle, and the dimming factor merely leads to an error in distance. However, a possible escape from the vicious circle is found in the following procedure. Since we know the intrinsic luminosities of nebulae, their apparent faintness furnishes two scales of distances depending upon whether we assume the nebulae to be stationary or receding. If, then, we analyze our data, if we map the observable region, using first one scale and then the other, we may find that the wrong scale leads to contradictions or at least to grave difficulties. Such attempts have been made and one scale does lead to trouble. It is the scale which includes the dimming factors of recession, which assumes that the universe is expanding.

Alternative Forms of the Law of Red Shifts

The project was carried out by the precise formulation of (a) the law of red shifts and (b) the large-scale distribution of nebulae. The form of the law of red shifts is most readily derived from the study of the brightest nebulae in the great clusters. These nebulae, as a class, are the most luminous bodies in the universe, and their spectra can be recorded out to the maximum distances. Furthermore, the clusters are so similar that the apparent faintness of the five or ten brightest members furnishes reliable relative distances. The observations now extend out to about 240 million light years where the red shift is about 13 per cent. of the normal wavelengths of the incoming light. Since the corresponding velocity of recession is the same fraction of the velocity of light, the nebulae in the most distant cluster observed, if they are actually receding, will appear 13 per cent. fainter than they would appear if they were stationary. The difference is small but, fortunately, the measures can be made with fair accuracy.

The results may be stated simply. If the nebulae are stationary, the law of red shifts is sensibly linear; red shifts are a constant multiple of distances. In other words, each unit of the light path contributes the same amount of red shift.



A QUADRUPLE SYSTEM OF NEBULAE

THE THREE SPIRALS, NGC 3185, 3187 AND 3190, TOGETHER WITH THE ELLIPTICAL SYSTEM, NGC 3193, FORM A QUADRUPLET LYING AT A DISTANCE OF ABOUT 7.5 MILLION LIGHT YEARS FROM THE EARTH.

On the other hand, if the nebulae are receding, and the dimming factors are applied, the scale of distances is altered and the law of red shifts is no longer linear. The rate of expansion increases more and more rapidly with distance. The significance of this result becomes

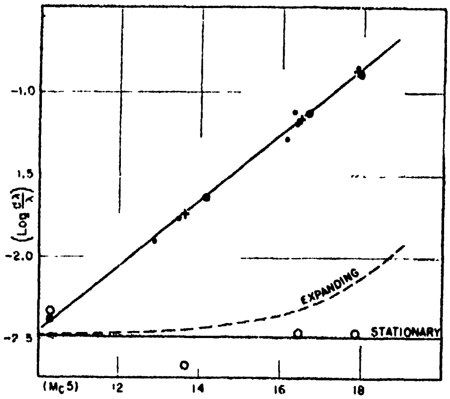


FIG. 1. THE LAW OF RED SHIFTS

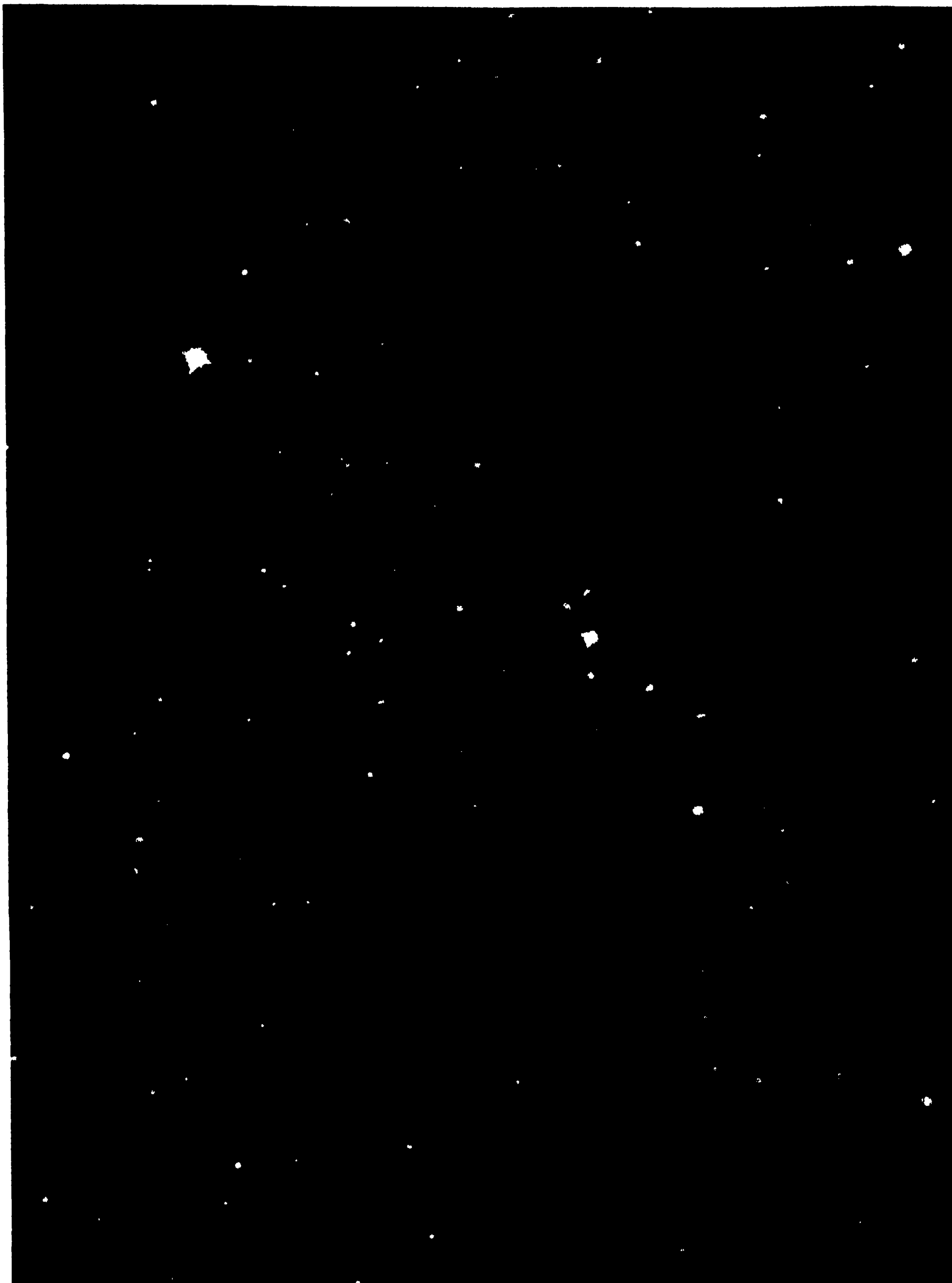
The law of red shifts at very great distances is derived as a relation between apparent magnitudes of the fifth brightest members of clusters and the mean red shifts observed in the clusters. The relation, log $d\lambda/\lambda = 0.2\ m_5 +$ constant, shown as a full line in the diagram, indicates a linear law of red shifts ($d\lambda/\lambda =$ constant $\times$ distance). In the diagram, large discs represent clusters of high weight; dots, clusters of low weight; crosses, weighted means. Observed magnitudes have been corrected for all known effects (including the "energy effects," $3d\lambda/\lambda$), except recession factors. Thus, for a stationary universe, the law of red shifts is sensibly linear. For an expanding universe, the recession factors would be applied, and the law would depart from the linear form. Such departures, shown by the broken curve, imply that the rate of expansion has been slowing down, and that the "age of the universe," the time since the expansion started, is less than 1,000 million years. The diagram includes minor revisions of the observational data in accordance with recent investigations.

clear when we reverse the picture. Light that reaches us to-day left the distant nebulae far back in the dim past—hundreds of millions of years ago. When we say that the rate of expansion increases with distance, we are saying that long ago the universe was expanding much faster than it is to-day, that, for the last several hundred million years at least, the rate of expansion has been slowing down. Therefore, the so-called "age of the universe," the time interval since the expansion began, is much shorter than the 1,800 million years suggested by a linear law of red shifts. If the measures are reliable, the interval would be less than 1,000 million years—a fraction of the age of the earth and comparable with the history of life on the earth. The nature of the expansion is permissible, and, in fact, specifies certain types of possible worlds. But the time scale is probably not acceptable. Either the measures are unreliable or red shifts do not represent expansion of the universe.

THE LARGE-SCALE DISTRIBUTION OF NEBULAE

If the new formulation of the law of red shifts were unsupported by other evidence, the implications would probably be disregarded. But similar discrepancies are met in quite independent studies of large-scale distribution. Five sampling surveys (four at Mount Wilson and one at Mount Hamilton) made with large reflectors, furnish the numbers of nebulae per unit area in the sky to successive limits of apparent faintness. The results furnish the numbers of nebulae per unit volume in five spheres whose radii range from about 155 to 420 million light years on the stationary distance scale, or about 145 to 365 million light years for the expanding distance scale.

On the assumption that red shifts do not represent actual recession, the large-scale distribution is sensibly homogeneous—the average number of nebulae per unit volume of space is much the same for each of the spheres. Further confirmation is found in some of the recent Harvard counts of nebulae which fall within the area of the sky covered by the



THE CORONA BOREALIS CLUSTER OF NEBULAE

THE GREAT CLUSTER IN CORONA BOREALIS IS AT A DISTANCE OF THE ORDER OF 135 MILLION LIGHT YEARS. IT IS A COMPACT SWARM OF SEVERAL HUNDRED NEBULAE, MAINLY OF THE ELLIPTICAL TYPE. ON THE PHOTOGRAPH OF THE CENTRAL REGION (MADE WITH THE 100-INCH REFLECTOR), THE NEBULAE ARE MORE NUMEROUS THAN THE STARS.

A SAMPLE OF THE UNIVERSE

THE PHOTOGRAPH (A NEGATIVE PRINT, INSTEAD OF THE USUAL POSITIVE, TO SHOW VERY FAINT IMAGES) IS ENLARGED FROM THE CENTRAL REGION OF A SURVEY PLATE MADE WITH THE 100-INCH REFLECTOR, USING A LONG EXPOSURE AND A FAST EMULSION. SCATTERED AMONG THE FOREGROUND STARS (WHICH BELONG TO OUR OWN STELLAR SYSTEM) ARE FOUND THE FAINT IMAGES OF MANY NEBULAE DISTRIBUTED THROUGH A CONE OF SPACE, WITH APEX AT THE OBSERVER, REACHING OUT TO A DISTANCE OF THE ORDER OF 400 MILLION LIGHT YEARS. SOME OF THE BRIGHTER IMAGES (DARK IN THIS NEGATIVE PRINT) ARE MARKED BY ARROWS. THE STUDY OF SUCH SAMPLES IN SURVEYS REACHING TO DIFFERENT DEPTHS, INDICATES THAT THE LARGE-SCALE DISTRIBUTION OF NEBULAE IS APPROXIMATELY UNIFORM THROUGHOUT THE OBSERVABLE REGION OF THE UNIVERSE.

deep surveys and which are based on the same scale of apparent faintness. Sufficient data can be extracted from the reports to determine a mean density over large areas extending out to perhaps 100 million light years, and the result is in substantial agreement with those of the earlier investigations. All these data lead to the very simple conception of a sensibly infinite, homogeneous universe of which the observable region is an insignificant sample.

The inclusion of dimming corrections for recession, because they alter the scale of distance in a non-linear way, necessarily destroys the homogeneity. The number of nebulae per unit volume now appears to increase systematically with distance in all directions. The result violates the cosmological principle of no favored position, and, consequently, is referred to some neglected factor in the calculations. If the density appeared to diminish outward, we should at once suspect the presence of internebular obscuration, or, perhaps, the existence of a super-system of nebulae. But an apparently increasing density offers a much more serious problem. About the only known, permissible interpretation is found in positive spatial curvature, which, by a sort of optical foreshortening, would crowd the observed nebulae into apparently smaller and smaller volumes of space as the distance increased.

Spatial curvature is an expected feature of an expanding universe, and, together with the precise form of the law of red shifts, further specifies a particular type of possible world. Thus, if the measures were reliable, we might conclude that the initial cosmological problem had been solved—that now we knew the nature of the universe we inhabit. But the situation is not so simple. Just as the departures from linearity in the law of red shifts indicate a universe that is strangely young, so the apparent departures from homogeneity indicate a universe that is strangely small and dense.

The sign of the curvature required to restore homogeneity is positive, hence the universe is "closed"—it has a finite volume, although, of course, there are no boundaries. The amount of curvature indicates the volume of the universe

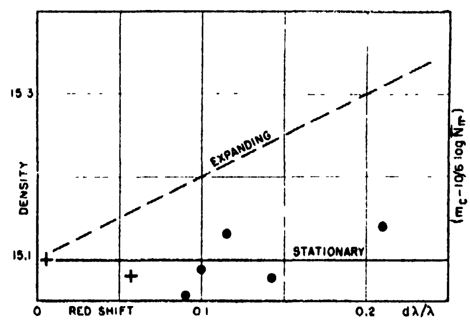


FIG. 2. LARGE-SCALE DISTRIBUTION OF NEBULAE

If N_m is the number of nebulae per square degree brighter than apparent magnitude m, then the average density (number of nebulae divided by volume of space), in arbitrary units, is represented by ($\log N_m - 0.6m$). Each point in the diagram represents a survey in which the observed *m* have been corrected for all known effects (including the "energy effects," 3 dλ/λ) but omitting the "recession factors," dλ/λ. The diagram indicates that, for a stationary universe, the density is independent of distance (or red shift). If the universe were expanding, "recession factors" should be applied, and the points would fall along the broken line, indicating that the density increases steadily with distance. In order to escape this conclusion, it is necessary to introduce still another effect, such as spatial curvature, which exactly compensates the recession factors. The dots represent surveys made at Mount Wilson and Mount Hamilton; the first cross, the Shapley-Ames survey to m = 13±; the second cross, Harvard counts to m = 17.5, extracted from *Proc. Nat. Acad.*, 24: 148, 1938, and 26: 166 and 554, 1940, and reduced according to the procedure used in reducing the deeper surveys.

—about four times the volume of the observable region. Such a universe would contain perhaps 400 million nebulae. The total mass, however, would be far greater than that which can be attributed to the nebulae alone.

Conclusion

Thus the use of dimming corrections leads to a particular kind of universe but one which most students are likely to reject as highly improbable. Furthermore, the strange features of this universe are merely the dimming corrections expressed in different terms. Omit the dimming factors, and the oddities vanish. We are left with the simple, even familiar concept of a sensibly infinite universe. All the difficulties are transferred to the interpretation of red shifts which can not then be the familiar velocity shifts.

Two further points may be mentioned. In the first place, the reference of red shifts to some hitherto unknown principle does not in any way destroy the validity of the theory of expanding universes. It merely removes the theory from immediate contact with observations. We may still suppose that the universe is either expanding or contracting but at a rate so slow that it can not now be disentangled from the gross effects of the superposed red shifts.

Secondly, the conclusions drawn from the empirical investigations involve the assumptions that the measures are reliable and the data are representative. These questions have been carefully reexamined during the past few years. Various minor revisions have been made but the end results remain substantially unchanged. By the usual criteria of probable errors, the data seem to be sufficiently consistent for their purpose. Nevertheless, the operations are delicate and the most significant data are found near the limits of the greatest telescopes. Under such conditions, it is always possible that the results may be affected by hidden systematic errors. Although no suggestion of such errors has been found, the possibility will persist until the investigations can be repeated with improved techniques and more powerful telescopes. Ultimately, the problem should be settled beyond question by the 200-inch reflector destined for Palomar. The range of that telescope, and the corresponding ranges of the dimming corrections, should be about twice those examined in the present investigations. Factors of 25 per cent. in the apparent brightness of nebulae at the limits of the spectrograph, and 40 to 50 per cent. at the limits of direct photography, should be unmistakable if they really exist.

Meanwhile, on the basis of the evidence now available, apparent discrepancies between theory and observation must be recognized. A choice is presented, as once before in the days of Copernicus, between a strangely small, finite universe and a sensibly infinite universe plus a new principle of nature.

SOIL AND WATER ECONOMY IN THE PUEBLO SOUTHWEST

I. FIELD STUDIES AT MESA VERDE AND NORTHERN ARIZONA

By Dr. GUY R. STEWART and Dr. MAURICE DONNELLY

SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

CENTURIES before the permanent settlement of America by white men the Pueblo Indians of the arid Southwest developed methods of soil and water conservation which they used effectively to maintain production of their crops of corn and beans. The extent and variety of these early American methods of soil and water conservation are the subject of former articles in THE SCIENTIFIC MONTHLY[1] and elsewhere.[2]

Since then further work has been carried out to try to determine the effectiveness in soil and water conservation of the agricultural practices of the first cultivators at four centers of Pueblo settlement. The locations studied were the Mesa Verde Plateau, the primitive villages adjacent to Navajo Mountain in northern Arizona, the ruins found on the northern rim of the Grand Canyon and the early settlements of the San Francisco Mountains. The general situation of these places of study is shown on the accompanying map of the Pueblo Plateau (Fig. 1). In addition, further examination was made of the systems of flood water irrigation in use at the present day on the Zuni Reservation in central New Mexico.

MESA VERDE PLATEAU

Fig. 2 shows the location of the areas on Chapin Mesa, Wickiup Canyon and Wetherill Mesa, where further detailed studies were made on the Mesa Verde Plateau. The flood water ditch mapped previously was traced for approximately three fourths of a mile above Mummy Lake, showing that this drainage way would have intercepted an appreciable portion of the runoff from the upper part of Chapin Mesa. It is possible that a branch of the ditch may have extended to the east, which would have picked up an intermittent stream flow from the west branch of Soda Canyon. Nordenskiold[3] reported indications of such a

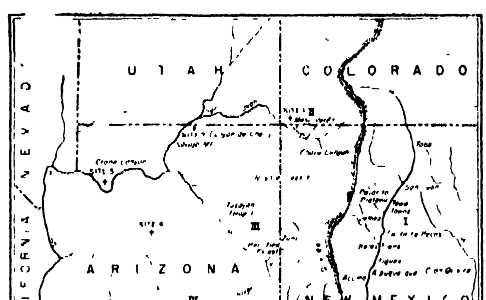


FIG. 1. MAP OF PUEBLO PLATEAU

PUEBLO CULTURE AREAS: I—RIO GRANDE; II—SAN JUAN; III—LITTLE COLORADO; IV—GILA; V—MIMBRES CHIHUAHUA. AFTER MAP BY SCHOOL OF AMERICAN RESEARCH.

[1] Guy R. Stewart, SCIENTIFIC MONTHLY, 51: 201–220 and 329–340, September and October, 1940.

[2] Guy R. Stewart, *Soil Conservation*, 5: 112–115, 1939.

[3] G. E. A. Nordenskiold, "The Cliff Dwellers of the Mesa Verde, Southwestern Colorado, Their Pottery and Implements."

supply feeder in his memoir describing conditions at Mesa Verde in 1889. John Wetherill,[4] in a discussion of evidences of early agriculture at Mesa Verde, has stated that he remembered seeing signs of such a ditch in his first visits to the plateau. This branch supply ditch could not be traced during the work in 1940.

Further soil profile studies along the flood-water ditch were made by H. K.

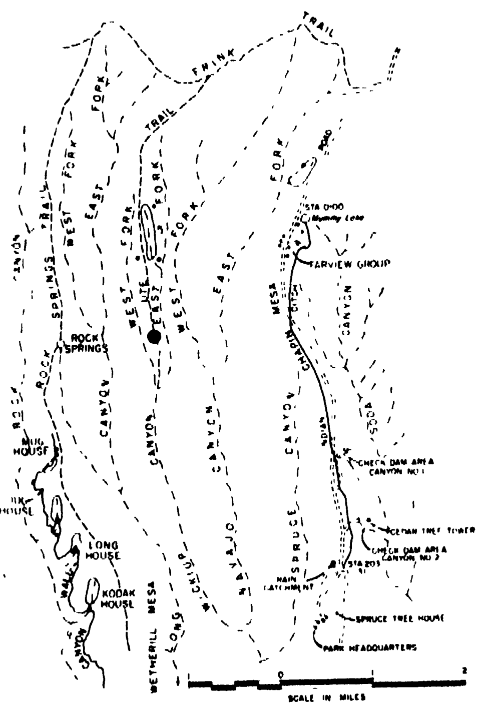


FIG. 2. LOCATION MAP
OF OLD INDIAN DAMS IN THE MESA VERDE NATIONAL PARK, COLORADO.

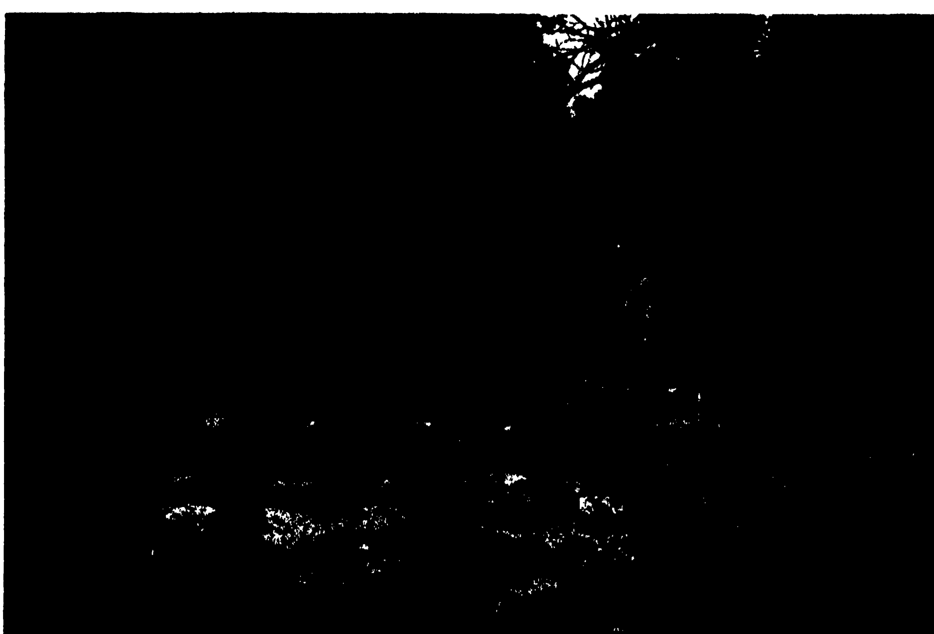
Woodward and the writers. These showed an adequate depth of loam or silt loam soil deposited in the ditch amounting to two feet or more at most points, so that crops of corn or beans could have been raised in the greater part of the broad waterway itself in the same manner that the present-day Hopis and Zunis plant the flood-water stream beds. In addition, a gently sloping area of several acres, just below the Far View group of ruins, still showed evidence of field checks made with small boulders, indicating that the water running down to the ditch was intercepted in places to supply fields along the way. Where the flood ditch first crossed the modern highway, there is the beginning of a series of fields, with a gentle slope of 1½ to 4 per cent., which have a relatively deep surface soil, thoroughly adequate for crop production if run-off were arrested and the rainfall supplemented by water from the uplands. The location of probable corn fields can be recognized at intervals, along the ditch, by noting the areas where water could be impounded with earth spreaders and simple field checks.

Local observers with whom the writers have discussed the value and importance of a supply ditch for flood water under the conditions found at Mesa Verde, have pointed out that the rainfall is probably only moderately higher in the uplands than it is along the lower part of Chapin Mesa. In answer to this it should be noted that the average rainfall of approximately 21 inches is well below the figure for rainfall in the corn-producing portions of the United States, amounting to about 35 inches for a sure crop. Though the strains of corn used by the Pueblo people were undoubtedly hardy and relatively drought-resistant, it appears likely that the 21-inch rainfall of Mesa Verde is lower than would be needed to produce maximum crops, even with specialized dry land types. With the lower rainfall of 7 to 8 inches occurring in much of the Hopi and Zuni country it is certain that appreciable amounts of supplementary moisture would be required. Even a slightly higher rainfall on the uplands at Mesa Verde would have supplied run-off which might have brought up the moisture on the lowland fields, when conducted there by the flood-water ditch, so that crop production would have been more cer-

[4] John Wetherill, personal communication, 1939.

MANCOS RIVER VALLEY IN COLORADO

THIS WAS THE ANCIENT THOROUGHFARE INTO THE MESA VERDE PLATEAU. VIEW UPSTREAM AT THE SOUTH END OF CHAPIN MESA.



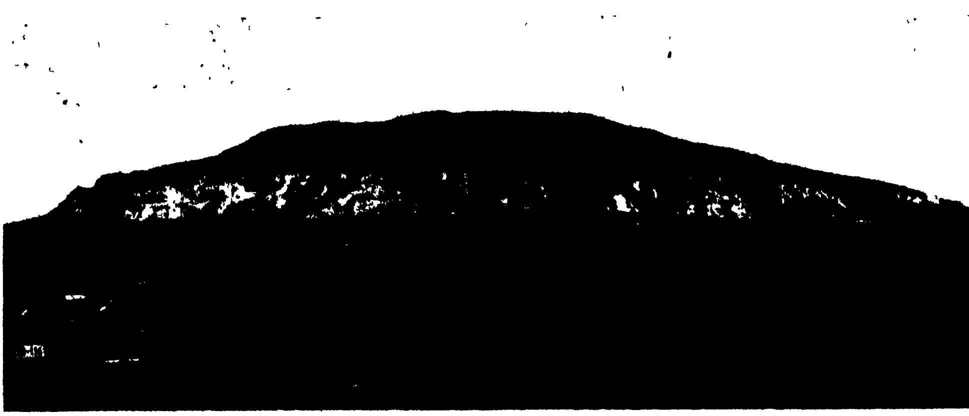
GROUP OF WIDE CHECK DAMS NEAR LONG HOUSE, WETHERILL MESA

FURNISHING VILLAGE GARDEN PLOTS ON THE MESA VERDE PLATEAU.

tain. The assurance of a bumper crop, even on corn belt standards of water requirement, would be reached in most years at Mesa Verde if the run-off water from an area of surrounding land equal to one half the size of the corn field were brought onto the flood-water planting, provided all rainfall falling directly on the field itself was arrested and held in place for crop use. In a land where water economy is of paramount importance, any chance for an additional water supply would justify the labor and effort for supplementary supply feeders, such as the flood-water ditch.

would have formed only small cultivated areas about 10 feet by 12 feet in size. All the checks at the Wetherill Mesa sites were unusually wide, ranging from 30 feet to 50 feet across and apparently formed level plots 20 to 50 feet between the checks, before the centers were washed out. An accompanying photograph shows one of the longer checks laid down on a flat platform of rock, with a second check largely washed out and a series of further checks behind, which were still partly effective.

The major part of the Mesa Verde check dams were laid down directly on



NAVAJO MOUNTAIN—A GREAT ROUNDED DOME OF SANDSTONE

solid sandstone. It is impossible to tell at this day whether the soil which was held by the checks was filled in by hand or whether the checks were built up by the gradual accumulation of soil suspended in flood run-off. Profile examinations showed that the checks contained originally about three feet of excellent surface soil. When abandonment took place and no repairs were made after freshet flows came down the water courses, it was inevitable that the centers of the dams would give way.

Studies were next made of two small groups of check dams on the upper part of Chapin Mesa, where the checks were in most cases about 20 feet long, with one check of 45 feet. These checks are located on a canyon of moderate slope and originally would have furnished small, level garden plots which could have been used by occupants of the Far View group of dwellings.

Following this a series of check dam sites on Wickiup Canyon and at three locations on Wetherill Mesa near Kodak House, Long House and below Jug House were examined. The checks on the upper part of Wickiup Canyon would have formed long level plots, while those lower down, being on a steep slope,

Preliminary examinations were next carried out of the evidences of primitive agriculture on Parke Mesa, which lies to the east beyond Spruce Canyon at Mesa Verde. Water detention checks were

WELL-PRESERVED CEREMONIAL KIVA
LOCATED ABOVE RAINBOW LODGE ON NAVAJO MOUNTAIN.

found around the principal ruins and a large group of check dam gardens were discovered on an east branch of Soda Canyon. In the fall of 1939, check dam areas had been found previously in tributaries of Little Moccasin Canyon.

A survey was made of the upper portions of Morefield, White and Waters Canyons, further east, without finding definite evidence of conservation works. Numerous ruins are located in all three sections visited, but the major part of these sites are dated by pottery shards as having been occupied in the period of

SMALL GARDEN PLOT
AT THE BASE OF NAVAJO MOUNTAIN, ABOVE RAINBOW LODGE.

BOULDER TERRACES ACROSS A FIELD
NEAR RED HOUSE RUIN, NAVAJO MOUNTAIN.

Pueblo II and earlier. The principal ruins on Parke Mesa, Chapin Mesa, Wickiup Canyon and Wetherill Mesa are believed to have been used through earlier periods into Pueblo III. This is the closing stage of the history of Pueblo life at Mesa Verde. The work of Douglass[5] and his associates had indicated that the final abandonment of Mesa Verde about 1300 A.D. came after a long drought. Should further work show that conservation structures are found associated largely with Pueblo III ruins on the plateau, it may indicate that the inhabitants turned to methods of soil and water saving late in the period of occupancy of this area. Was it a discovery brought in from elsewhere in the Southwest or did some inventive leader devise the check dams and flood water ditch system from observation of the flow of water and washing of soil on the local fields? The only hope of an answer will be to carry out further comparative studies of the types of check dam and ditch construction in other parts of the Pueblo country before an attempt is made to establish forms of related use and construction. Owing to the extent of the Mesa Verde Plateau there are still portions which should be visited and signs of agricultural use examined before tentative answers are proposed to these tantalizing questions.

5 A. E. Douglass, *Nat. Geographic Mag.*, 6: 737–770, 1929.

Navajo Mountain Area

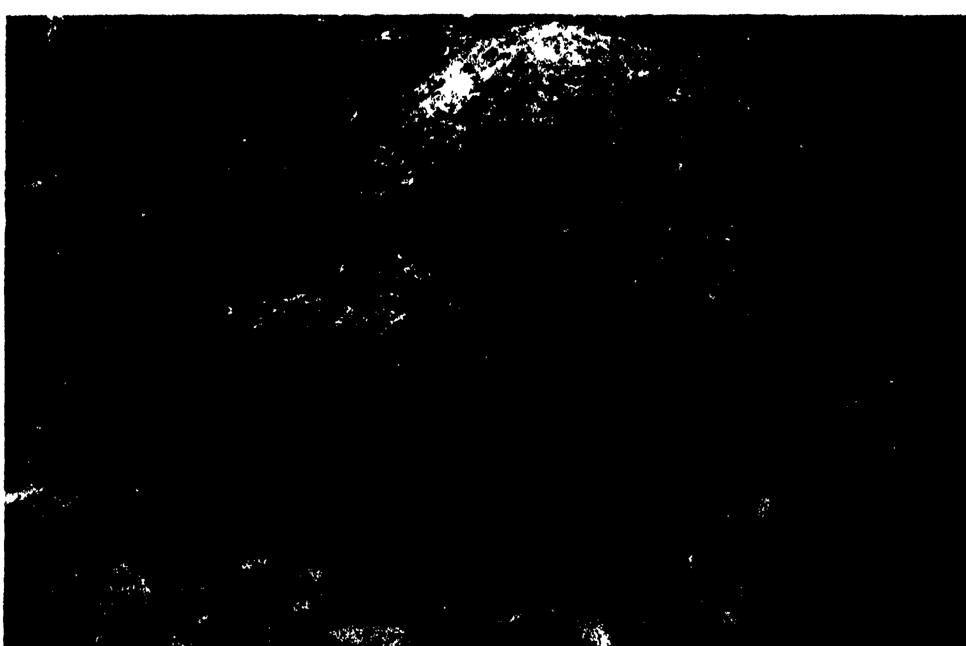
The country surrounding Navajo Mountain, which lies just above the extreme northern border of Arizona, was a notable center of early Pueblo life. The mountain itself is a great rounded dome of sandstone, the top of which is of Cretaceous and the slopes probably of Jurassic age. One of the larger sites lying near the southeastern side of the mountain is Red House Ruin, so called because it was constructed of red sandstone country rock. Two types of conservation structures were found adjacent to this ruin. The first of these were stream checks which were roughly made of local rock from the stream channels. Although the main part of these rocks are still in place, the garden plots were on a slight slope of 1½ to 3 per cent. grade, and the surface soil has been almost com-

pletely removed, leaving an erosion pavement of variable sized rocky fragments.

A second type of water retention device was installed across the fields below and to the west of the ruin. This consisted of a type of simple boulder field terrace, designed to stabilize notably larger areas than the stream checks. These terraces were installed on slopes of 4 to 6 per cent. and produced a slightly sloping terraced area from which most of the soil has now departed. Gordon B. Page visited the ruin in a period of inclement weather and mapped some 23 field terraces adjacent to Red House Ruin. In addition, the writers found several groups of stream and field checks farther to the west. The first of these were stream checks installed in a small wash close to the ruin where the garden plots had lost all surface soil.

The next large wash to the west had been so heavily eroded by torrential runoff that stream checks were no longer recognizable. However, the four small draws beyond, continuing towards the west, were found to have groups of 10 to 12 checks in each in varying states of preservation. The original service of these conservation measures was the protection of an area that apparently included most of the village corn lands. The major part of the soils of the area appear to have been loose, open, sandy loams, which offered little resistance to erosion unless protected by vegetation. In recent times the entire site and its surroundings have been heavily grazed by bands of Navajo sheep so that grass and palatable herbage have been almost completely consumed, with resultant heavy washing of the surface soil after every rain.

At the base of Navajo Mountain, above Rainbow Lodge, several small garden plots were found near a well-preserved ceremonial kiva and primitive rock shelters. Here the garden plots were more nearly level and the surface soil had only been partly lost. An excellent instance of field scale checks was found across the land lying further down the mountain,



ROCK SHELTER, ABOVE RAINBOW LODGE, NAVAJO MOUNTAIN

approximately a half mile below Rainbow Lodge. Both stream and field checks were placed on land with about a 6 per cent. slope from which most of the surface soil has now been lost. Two field shelters, or food storage ruins, were found close to the former corn fields, testifying to the regular use made of these areas. Approximately two miles from these fields, along the canyon to the west, lies the Tohalena Gardens, formerly used by the Pueblos and now partly cultivated by present-day Navajos. This consists of a group of gardens, stabilized by boulder checks, where excellent surface soil remains. The land is watered by a permanent spring and is similar to the smaller groups of Hopi terrace gardens.

The time of occupancy of the Navajo Mountain ruins appears to have been largely during Pueblo III, tree-ring analysis having dated timbers from the Red House Ruin at A.D. 1143. Pottery shards were collected near Red House Ruin, as well as from the ruins adjacent to Rainbow Lodge and were likewise classified by Dr. H. S. Colton as being of the Pueblo III period.

Grand Canyon, North Rim

The North Rim of the Grand Canyon, especially on the Walhalla Plateau, was a thickly settled center of early Pueblo ruins of the small village type. Louis Schellbach, assistant park naturalist, aided the writers with information and also made Edward Hall's Archaeological Survey of the Walhalla area available to us.[6] The Walhalla Plateau consists of a rolling upland lying adjacent to the Grand Canyon gorge at elevations of 8,000 to 8,400 feet. The topography consists of a series of gently sloping ridges rising 200 to 400 feet above the intervening valleys. The tops of many of the ridges are broad and relatively flat so that slightly sloping land occurs along the crests of the hills. At the present time the uplands are covered with an open stand of ponderosa pine, which extends across part of the valleys, intermingled with groves of aspen. The early Pueblo settlements were nearly all located along the sides or crests of the hills so that the vilages would have com-

LOWER PART OF A GROUP OF STREAM CHECK DAM GARDENS
ON THE NORTH RIM OF THE GRAND CANYON.

[6] Edward Hall, "An Archaeological Survey of the Walhalla Glades, Grand Canyon, Arizona." Masters' Thesis, University of Arizona, Tucson, Arizona, 1938, Manuscript.

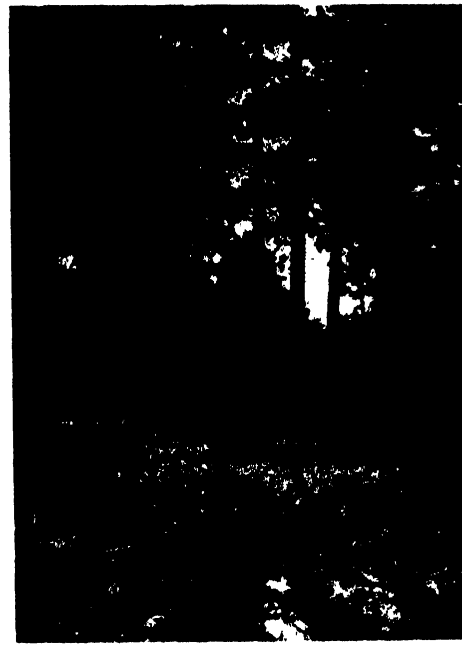
manded a view from one to another had the tree growth been thinner than at present, as was likely the case where agriculture was practiced actively.

A few boulder checks extending from 50 to 120 feet in length were found near many of the villages. Even three such checks would have helped to retain enough of the 27-inch rainfall, supplemented with run-off from adjacent land, for a village garden of ½ to 1 acre. Two long groups of stream check dams of 14 to 16 in number were found, one badly washed out and the other clearly recognizable, even though all surface soil had been lost from the slightly sloping checks laid down on a gradient of 8 to 10 per cent.

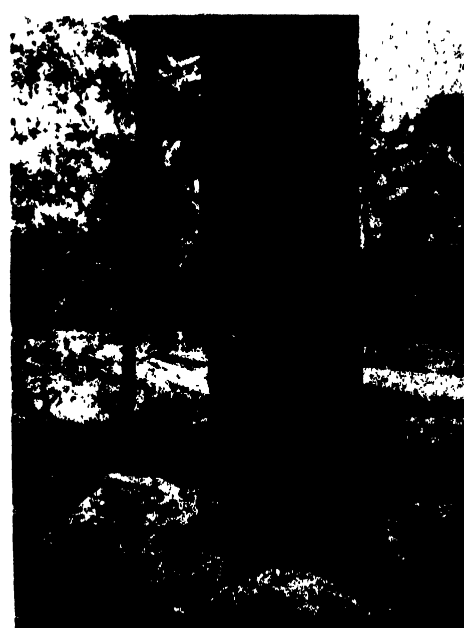
The largest agricultural site discovered in this section was on the side of a broad ridge of 8½ per cent. grade, near ruins 397 and 398 of Hall's survey, and covered an area of approximately 6 acres. The land was protected by long terraces of large, flat rocks at the bottom of the field extending some 800 feet in length. Further up the slope the material available was smaller and the boulder terraces were made up of a broad band of a number of rows of rock.

At the present day, with the moderate stand of Ponderosa pine there is a protective cover of about 2 inches of pine needles over most of the ground. This should give adequate protection against washing by rains. Profile studies showed the greater part of the surface soil had been removed with the formation of an erosion pavement. This suggests that there may have been a considerable period when the fields were exposed to surface washing after Pueblo occupation ended. Pottery shards examined by Dr. Colton appear to show the time of use of these sites extended from late Pueblo II, through Pueblo III.

The high elevation of the Walhalla Plateau, in excess of 8,000 feet, must have made it difficult to mature a corn



SWAMP POINT VILLAGE SITE
WITH A SMALL RUIN IN THE FOREGROUND.



PONDEROSA PINE
COMPLETELY FILLING A SMALL SHELTER AT THE SWAMP POINT VILLAGE SITE.

crop every season because of a relatively short frost-free period. Possibly the comparatively abundant rainfall may have compensated for this difficulty and continuous planting of early maturing ears of corn may possibly have developed a strain with a short growing period.

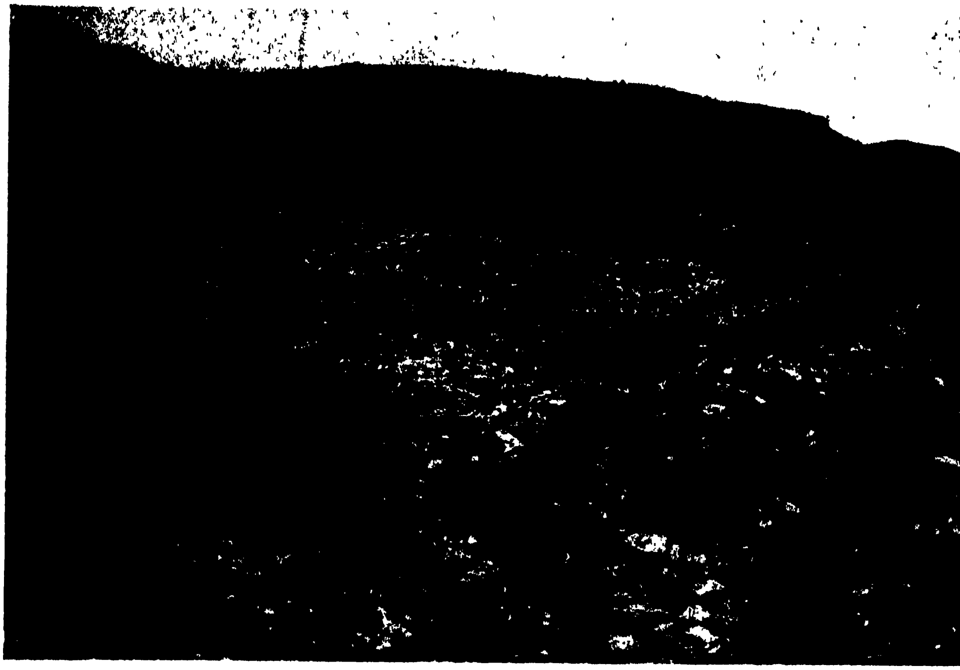
The winters on the North Rim are notably more severe than on the south side of the canyon, so it would not be surprising if the early residents had moved down into the canyon during the most rigorous weather of midwinter, though a shifting existence has not usually been associated with the settled Pueblo villages.

The portions of the Grand Canyon near at hand embrace some of the most striking scenery on the North Rim, ranging from Point Imperial up to Cape Royale with villages in sight of the great gorge nearly all the way. Probably the depth and steepness of the canyon were more valued for the protection afforded from enemies than for the scenic beauty which charms the modern visitor.

Most persons coming to the Grand Canyon at the present day have heard reports of the vast size of the chasm extending 10 to 12 miles across, from the north to the south rim, and reaching down over a mile to the actual stream bed. The first white visitors who reached the canyon on the south side had no such background of information. In the fall of the year 1540 Garcia Lopez de Cardenas and 12 soldiers of Coronado's expedition made the trip of 120 miles from Awatobi in the Hopi villages, with a party of Indian guides. Students of Grand Canyon history believe the Spaniards and their Hopi companions reached a point along the south rim where the canyon is as deep as it is opposite the Walhalla Plateau. Castaneda[7] in his account of the Coronado expedition tells how Cardenas and his men came to the river, where they spent three days looking over the country and hunting for a passage down to the stream. None of the Spaniards at first believed the Indians when they told the Spaniards the size of the gorge or that the lower river bed was half a league wide. Finally

PRINCIPAL PORTION OF WUPATKI RUIN

[7] F. W. Hodge, "The Narrative of the Expedition of Coronado by Pedro de Castaneda." In "Spanish Explorers in the Southern United States, 1528–1543," pp. 275–387. New York, 1907.



HILLSIDE GARDEN PLOT

NEAR WUPATKI RUIN, LYING ON A FIVE PER CENT. SLOPE.

BOULDER CHECKS FOR WIND EROSION CONTROL

RUNNING DOWN THE SLOPE NEAR THE WUPATKI NATIONAL MONUMENT.

VIEW OF CITADEL RUIN, WUPATKI NATIONAL MONUMENT
SHOWING THREE ROUGH TERRACES BELOW THE RUIN.

three of the most active Spaniards climbed down about a third of the distance from the upper rim and then had difficulty in scaling the cliffs again. When they returned they informed Cardenas that the rocks down below them which looked quite small were in reality bigger than the great tower of Seville.

Further studies of ruins in the western part of the Walhalla Plateau showed that one ruin, Grand Canyon Number 383, located on the top of a relatively level ridge, was surrounded by some 24 garden plots scattered at random over the area adjacent to the ruin. These plots varied in size from 10 feet by 12 feet up to 75 feet by 15 feet. The material used to form the borders of these plots was relatively small rock, which was probably reinforced by brush and soil to retain the rainfall and impound any run-off which came down the gentle slope.

Preliminary examination of ruins near Swamp Point, towards the Powell Plateau, lying over 40 miles from the Walhalla sites, revealed a series of long boulder checks near a small village site and showed the wide distribution of conservation work on the North Rim.

San Francisco Mountain District

The country in the San Francisco Mountains, surrounding Sunset Crater and other recent cinder cones, was comparatively thinly settled with scattered small Pueblo communities prior to the cinder and ash eruptions which have been dated by Colton[8] as having occurred about 885 A.D. Surveys made by the Museum of Northern Arizona[9] showed a rapid increase in early settlement in the period from 900 to 1000 A.D., with the maximum number of primitive sites occupied in the period from 1100 to 1200 A.D. Colton has suggested that the presence of the volcanic ash was highly beneficial to the agricultural use of the land and made it possible to cultivate corn on many fields, formerly unproductive. The recent work of Duley[10] upon the infiltration of water into soils under vegetative mulches has shown that one great value of such mulches is that they pre-

8 H. S. Colton, *Geo. Review*, 22: 582–590, 1932.

9 Harold S. Colton, *Bull.* 104, pp. 1–68, 1932. Smithsonian Institution, Bureau of American Ethnology.

10 F. L. Duley, *Proceedings*, Soil Science Society of America, pp. 60–64, 1939.

CHAVEZ PASS SITE
SHOWING LARGE TERRACE WITH PRIMITIVE RESERVOIR TO COLLECT SURFACE RUN OFF.

vent puddling and sealing of the surface soil, a process which occurs when raindrops fall directly upon bare soil containing fine particles. Under a vegetative mulch the passage of water into the soil continues at a steady rate so that run-off and soil washing are both reduced. Infiltration effects similar to those obtained from vegetative mulches may be obtained from mineral mulches if they do not break down with raindrop impact into a fine suspension. Many kinds of volcanic ash are lacking in particles of colloidal size, hence a surficial deposit of such volcanic ash would insure good infiltration of precipitation. Colton's hypothesis receives support from this fact of the effect of volcanic ash on infiltration of precipitated moisture.

Preliminary studies of evidences of early agriculture in this section were made by the writers, especially around the ruins north of the San Francisco Peaks included in the Wupatki National Monument. Several groups of village garden plots are located adjacent to the principal ruins. Three of the best-formed terrace gardens are on the north side of the Citadel Ruin. The upper plot was 74 by 39 feet with about a 3½ per cent. slope, the middle 33 by 103 feet with a 5½ per cent. grade, and the lowest plot was 84 by 6 feet, lying approximately level. Dr. Colton informed one of us that profile excavations were made in these terraces at the time of the reconstruction of the Citadel Ruin and showed the sloping terraces were formed by filling in with village refuse. This could indicate these plots were highly productive garden areas when they were in use, though the upper surface soil has been removed by run-off since the period of occupation ended about 1200 A.D.

A set of very simple sloping terraces lie on the hillside to the southeast of the principal portion of Wupatki Ruin. Here a series of six plots with a slope of 3 to 4 per cent. have been made by digging into the hill behind, the size of the individual garden plots ranging from 18 feet by 19 feet up to 24 by 18 feet. At the present day a rocky erosion pavement covers the plots, through the washing away of surface soil on the exposed slope.

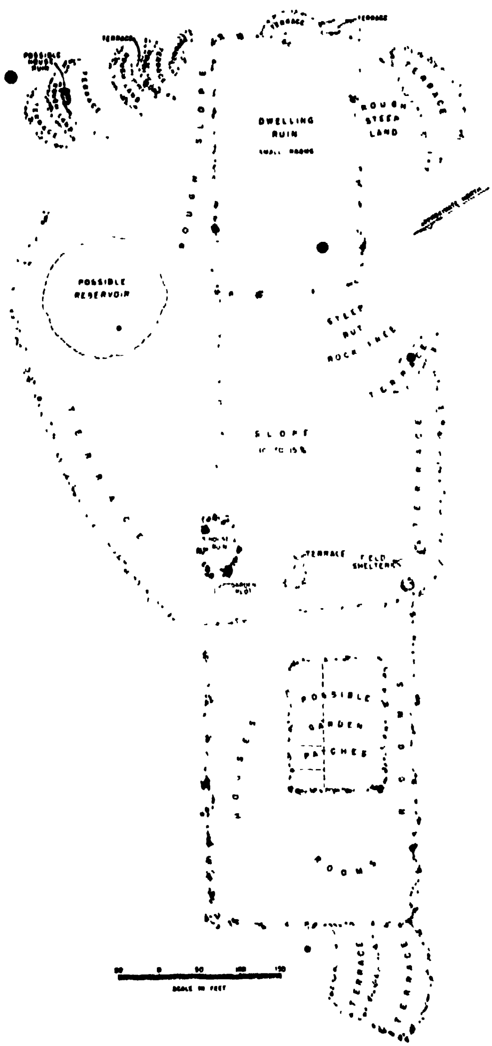


FIG. 3. CHAVEZ PASS SITE IN ARIZONA

An interesting group of fields were examined in company with David J. Jones, custodian of the Wupatki National Monument. These fields lie some 2 miles from the main Wupatki ruin. The area consists of a series of sloping tracts of land with a gradient of 5 to 6 per cent. towards the south and southwest. The entire site was covered with coarse black cinders of variable depth, in most places approximately over six inches of deposit. Several series of boulder checks were found on the exposed parts of the tract running up and down the slope, the checks being spaced approximately six feet apart. These checks would have given protection from the prevailing east and west winds and were probably reinforced with brush in the same manner that the Hopis reduce wind damage at the present day.

The Chavez Pass site is a large double ruin, lying some 50 miles southeast of Sunset Crater and was outside of the area of the cinder and ash eruptions that came from this cone. The inhabitants, however, are generally considered to have belonged to the same Pueblo culture group as those settling in the San Francisco Mountain district. The village was placed at the point of a steep hill with sloping land on three sides. Fig. 3 shows a sketch map of the site, as well as the probable agricultural use made of the adjacent land during the period of occupancy extending from Pueblo III into Pueblo IV.

The areas labeled "Terraces" were the plots adjacent to the ruins which would have made excellent gardens during the time the village was in use. All this land would receive some additional water from local run-off. The possible reservoir for collecting surface water is an interesting feature of this ruin and consisted of a circular excavation 150 feet in circumference and some 6 to 8 feet deep at the center. Colton[11] and others are of the opinion that the use of local water sources such as this may have been one of the principal reasons for the abandonment of many early Pueblo centers. The agricultural land in the terrace plots in most cases had a slope of 1½ to 3 per cent. and the surface soil has suffered appreciable loss. The large terrace surrounding the reservoir is nearly level and more of the surface horizon has been retained than on the balance of the land.

(To be concluded)

[11] H. S. Colton, *Science*, 84: 2181, 337–343, 1936.

THE OLDER DRIFT OF WISCONSIN

By C. G. STRATTON

HEAD, DEPARTMENT OF GEOLOGY AND GEOGRAPHY, STATE TEACHERS COLLEGE, RIVER FALLS, WIS.

REACHING from the western border of Wisconsin in Pierce and St. Croix counties eastward to the neighborhood of Merrill, Wausau and Wisconsin Rapids is the region of Older Drift. The last—Wisconsin—glacial invasion did not reach it except to send fingers of outwash along some of the southward flowing streams. On the north, the region is bounded by the great Kettle Moraine of the Wisconsin glacier and its associated outwash. To the south and east is the Driftless Area. The boundary separating the Older Drift region from the Driftless Area is rather ill-defined due to the absence of any well-marked, continuous terminal moraine such as marks the terminus of the Wisconsin glacier. Hummocky recessional moraines are, however, not uncommon in the region of Older Drift. The topography of the region is varied, as is well illustrated by the soil map. The region includes parts of the Western Upland, the Central Plain and the Northern Highland. The characteristic rocks and preglacial topography of each area strongly affect the soils and surface features of the corresponding parts of the Older Drift region. The observations here recorded were made mostly on the Western Upland in Pierce and St. Croix counties.

THE LOESS

Where not removed or buried by stream action, a deposit of buff-colored loess covers a part of the older drift. It is thickest near the bluffs overlooking the Mississippi, where it may be fifteen or twenty feet in depth, gradually thinning out to the north and east. It covers the southern half of Pierce County and the western part of Pepin County. It sends a finger north along the west side of Dunn County just to the east of the limestone escarpment marking the border of the Western Upland. This fine-grained, even-textured material is generally supposed to have been wind-deposited. It is the same as the loess of the Driftless Area and was apparently laid down during the same period. Its source may have been the outwash along the Mississippi. At any rate, its presence suggests a time when wind work was very active. Since the loess overlies the older drift and is absent on the younger drift, it was probably deposited during the period of the Wisconsin invasion or the preceding Peorian interglacial period, possibly during both periods. It is interesting to speculate on the conditions prevailing over that portion of the area not covered with loess.

WIND-POLISHED BOULDERS

A partial answer to the question just suggested is found in the character of the glacial boulders. Those at the surface, in the region of Older Drift, show the unmistakable evidence of profound scouring by wind-driven sand and dust. Quartzites and resistant sandstones are polished and fluted (Fig. 1, *left*). Igneous rocks of uneven resistance are pitted. Amygdaloids are found with the harder nodules projecting and with trails of the softer rock extending to the leeward side, protected by the more resistant nodules. Even-textured rocks as basalts and some quartzites have the typical "Dreikanter" shape (Fig. 1, *middle* and *right*). Pebbles of this type are especially abundant and may be found by hundreds in an hour's time. If at the surface, even large boulders weighing a

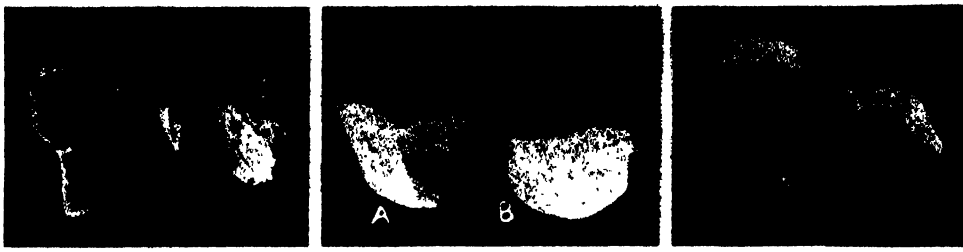


FIG. 1. WIND ETCHING
Left: ON PEBBLES OF SANDSTONE AND QUARTZITE. *Middle:* ON IGNEOUS ROCKS; (A) FINE-GRAINED GRANITE; (B) BASALT. *Right:* ON BASALT PEBBLES.

ton or more each often show a dreikanter shape. Perhaps half of the boulders in an average farm stone pile show evidence of wind abrasion.

None of these wind-etched pebbles and boulders were observed on the surface of the younger drift and only at or near the surface of the older drift. However, a number of large boulders which were uncovered in a gravel pit near St. Croix Falls, Wisconsin, were seen to be thoroughly etched. This is a region covered with Wisconsin drift. Surface pebbles in the same locality showed no signs of etching. This suggests that the etching was accomplished in this case before the final advance of the glacier which covered them with red outwash, the source of the gravel. Etching is little in evidence on the level lowlands of earlier outwash in Pierce and St. Croix counties since these are generally well covered by a dark prairie soil, possibly largely derived from the same wind-driven dust as the buff covered loess to the south. But wherever an outlier or a glacially deposited hummock projects above the later deposits, there the pebbles and boulders are consistently etched and polished. Etched pebbles are abundant also along the older terraces of the Kinnickinnic, Rush and Eau Galle rivers, streams which rise within the region of Older Drift. No field work was done along streams such as the Chippewa and the Black, the headwaters of which are in the younger drift to the north.

The question arises as to whether the drift beneath the loess also shows the effects of wind abrasion. Examination of the few available exposures along roads and gullies which are cut through the loess discloses a considerable number of pebbles which are apparently wind-polished, but the more conclusive dreikanter type, showing prolonged wind work, is not in evidence. Further search and more favorable exposures are needed before this point can be settled.

Agates

The Older Drift region in Wisconsin, although not covered by the Wisconsin glacier, was invaded at least twice and perhaps three times by earlier ice sheets. When geologists describe the deposits of the Wisconsin invasion they speak of the "Red" drift, deposited by ice crossing the iron measures and therefore containing much reddish material, and the "Gray" drift which came with the Keewatin ice and so missed the iron-bearing formations. The older drift is also red or gray and probably for similar reasons.

In the red drift of both the older and the younger ice sheets are great numbers of agates, generally known as "Lake Superior" agates. Locally, they are called "Carnelians," since most of them contain red chard or carnelian. Red gravels contain innumerable fragments of them. Occasionally they are found up to four or five inches in diameter. Some are of remarkable beauty and when free from cracks make excellent

material for the lapidary (Fig. 2, *top, left*). They are found in a great variety of patterns. Colors are mostly white, pink and red. Examination of many specimens can not but arouse curiosity as to their origin, a point upon which mineralogists seem unable to agree.[1] Most do agree that the agates were deposited in rock cavities. It is not clear, however, whether they came from silica gel (a colloidal solution) or from a pure solution in waters carrying alkali salts. Neither is it clear as to how the materials reached the cavities, whether through feeding tubes or, through pressure, between the microscopic crystals said to make up the chalcedony. Nearly all agree that they grew or developed from the outside toward the center.

Many of these agates contain geodes in the center with the quartz crystals pointing inward. Rarely the crystals are amethyst. Not uncommonly the nodule consists of alternate bands of chalcedony and crystal quartz. In this case often one can make out the layers of inward pointing crystals and the next inner layers of chalcedony laid down over the rough points of the crystals (Fig. 2, *top, right*). Additional layers of agate smooth out because the deposit is thicker in the depressions and thinner on the points. This indicates that the crystals were formed before the next inner band of agate and (perhaps) constitutes an argument against the current theory that the entire agate was formed from a mass of silica gel. It would seem that in order to lay down these alternate bands of agate and crystal quartz the solution must change, perhaps in the amount or nature of impurities present, perhaps from a pure to a colloidal solution and back again. Some specimens show a half dozen or more of these alternating lay-

[1] An excellent discussion may be found in chapters 10 and 11, "Quartz Family Minerals," by Dake, Fleener and Wilson.

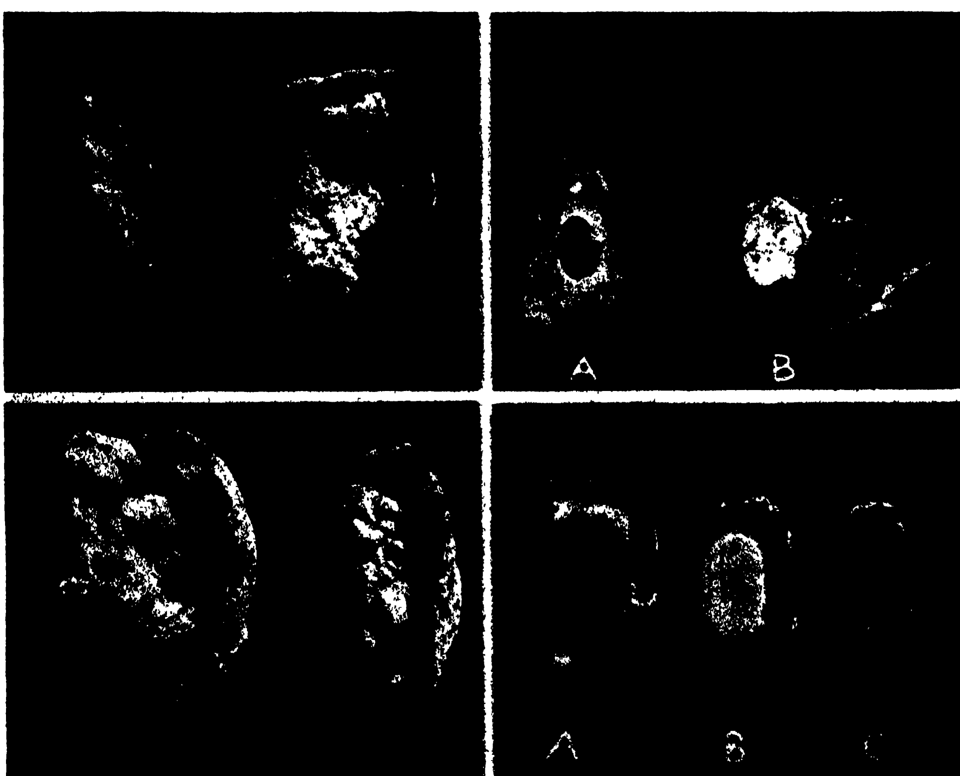
FIG. 2. EXAMPLES OF AGATES
Top: left: TYPICAL LAKE SUPERIOR AGATES. *Right:* AGATES SHOWING ALTERNATING BANDS OF CHALCEDONY AND CRYSTAL QUARTZ. *Bottom: left:* AGATES SHOWING THICKENING OF THE LAYERS IN ANGLES. *Middle:* CROSS SECTION SHOWING "FISH EYE." *Right:* "TUBULAR" AGATES.

ers. It is also interesting to note that in the case of agates the cross-sections of which show sharp angles in the layers, "Fortification" agates, the layers are often much thicker in the angles, thus in some cases doing away with angles as the center is approached and adding a pleasing variety to the pattern of the polished specimen (Fig. 2, *bottom, left*).

Few of these agates show evidence of "feeding tubes" through which the solution may have entered the cavity. Occasionally one is found in which the tubes or something resembling tubes does exist and seems to have a distinct relation to the pattern of the bands (Fig. 2, *bottom right*). Such are known locally as "tubular" agates.

The most admired pattern is known as a "Fish Eye," a name which describes it adequately. Fish-eye agates if suitable for cutting are highly prized. The presence and position of fish eyes in an agate, unless already exposed, can only be guessed at. Once in a while, when agates are sawed, a lucky cut will show a cross-section of a fish eye (Fig. 2, *bottom middle*). It is then seen that they are not spheres, as one might suppose, but hemispheres. They apparently started as bubbles of silica gel adhering to the inner wall of the cavity. Subsequent layers of agate conform to their outlines.

In view of the peculiarities described above, it seems reasonable to suppose that these agates were not formed by the hardening and color segregation of a mass of silica gel but as layers by a varying solution. Whatever their origin,



IRON CONCRETIONS

Top: left: WITH CORE OF FINE SAND. *Right:* (A) CORE OF CLAY HAS SHRUNK, LEAVING CAVITY; (B) WITH CORE OF COARSE SAND. *Bottom: left:* SHOWING BOTRYOIDAL SHAPE OF SOME IRON CONCRETIONS. *Right:* (A) AND (B) WITH CORES OF SILTSTONE; (C) WITH CORE OF CLAY.

they are an interesting feature of the older drift terrain and give much pleasure to the many people who search for them.

Iron Concretions

Fragments of iron concretions are common in the older drift. In some gravel pits in the western part of the older drift sheets, iron concretions are so abundant, large and well preserved as to attract considerable attention. Strangely enough, they are apparently more numerous in the gray drift than in the red. They are mostly limonite, although bands of hematite are sometimes present. Typically, they appear to consist of shells of iron oxide containing cores of clay or sand. When dried, the material of the inner core may shrink, leaving a distinct hollow (Fig. 3, *top right*, A). Some are compound with several cavities in one specimen. When broken these give rise to fantastic names such as "Petrified Walnut" and even "Petrified Indian's Heart." A more puzzling type, sometimes quite large, has a core of rather hard siltstone (Fig. 3, *bottom right*, A and B). The core, whether of sand, clay or siltstone, is stained by iron oxide to a buff or, more rarely, a reddish color. It seems that the concretion grew in a bed of sand or of whatever material forms the core. The iron oxide was deposited among the particles of the original formation, cementing them together but not necessarily displacing them. Specimen B, Fig. 3, *top right*, has a core of coarse sand. The same kind of sand makes up a large percentage of the outer shell.

What strange whim of nature causes the iron oxide to prefer the periphery of the concretion to the core? The explanation may lie in the work of the iron-fixing bacteria. Various species of these bacteria have been studied and described. Their life processes involve the oxidation of soluble iron compounds to the insoluble oxide. It is possible to imagine a colony of iron-fixing bacteria gaining a foothold in a formation supplying the solutions necessary for their propagation. The colony grows larger and throws down the insoluble iron oxide. In time this iron oxide must impede the movement of ground water to the disadvantage of those bacteria near the center. Those on the outside thrive and build a shell of closely cemented material. Those on the inside die out as their supply of ground water diminishes. Theoretically, this process continues as long as the solution is favorable or until the whole formation is a mass of concretions. The latter theory may not be too far-fetched, since many iron ores are concretionary in structure.

The growth of the concretions under discussion was evidently interrupted while they were still separate. However, the fact that some of them are compound would indicate that several colonies of bacteria occasionally merged into one, resulting in several cavities in one specimen. The botryoidal appearance of many iron concretions also suggests the action of colonial bacteria (Fig. 3, *bottom left*). Similar shapes suggest the possibility of bacterial work in the formation of "Mammillary" iron ore and "Grape Ore."

The shape of sand and clay concretions suggests the possibility of bacterial action. Bacteriologists describe sulfur-fixing bacteria. They describe the action of bacteria in preserving humus and peat. They mention the possibility of bacterial influences in the evolution of petroleum. It may well be that bacteria play important parts in many other geological processes and that here is a rich field, almost unexplored, awaiting investigation by properly trained scientists.

MATHEMATICS AND THE MAXIMUM SCIENTIFIC EFFORT IN TOTAL WAR

By Dr. MARSTON MORSE

THE INSTITUTE FOR ADVANCED STUDY; PRESIDENT OF THE AMERICAN MATHEMATICAL SOCIETY

MY subject is of concern not only to scientists but also to all those who are interested in a maximum effort to win the war. Every teacher and scientist is in fact, if not in law, a member of the great army fighting this war. Teachers of mathematics are primarily interested in the teaching of mathematics, but they are also interested in science as a whole, in particular in scientific research for military and industrial purposes and in education for the technical services of our army and navy. There is also the problem of the proper use of scientific men in time of war. Finally, they are concerned with the broad problem of education for freedom and democracy and believe that mathematics enters here again in a different but equally important role.

On March 3 of 1863, at the time of the Civil War, Abraham Lincoln approved an Act of Congress incorporating the National Academy of Sciences. Among the first members were the naturalist, Louis Agassiz, and the mathematician, Benjamin Peirce. High officers of the army and navy were included. In the words of the Act

> . . . the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments, and reports to be paid from appropriations which may be made for the purpose, but the Academy shall receive no compensation whatever for any services to the Government of the United States.

Here was the first formal use of scientists by the United States Government.

In 1916 President Wilson established the National Research Council to facilitate communication between the government and the National Academy of Sciences. The council was still subject to the condition of receiving no pay. To carry on extensive investigations involving laboratory, traveling and secretarial expenses, and the expense of assembling groups of men in one place, these older organizations have required supplementation. In June of last year the Office of Scientific Research and Development was established by executive order. The chairman is Dr. Vannevar Bush. There are three subcommittees. Besides the older National Advisory Committee on Aeronautics, there is the National Research Defense Committee, with President Conant, of Harvard, as chairman, and the Committee on Medical Research, with Dr. Newton Richards as chairman.

The higher officers of these committees work without compensation from the government. The final research and technical development are carried on in the form of projects found in various universities and industries. Part of the expense, usually the salary, is borne by the university or industry, and another part of the expense, usually the overhead, is borne by the government. Some two or three thousand scientists are involved. That remarkable work is being done I have every reason to believe.

Mathematicians are being used in this research to a small extent but not to the extent to which engineers and physicists are used. This was inevitable at the beginning when the need was greatest for the rapid attainment of special objectives. It is clear that the machine nature of modern warfare places engineering

skill at a premium. But the war is much more than a war of machines, it is a war of invention, and of a new and more mathematical use of machines. In this connection I shall quote Dr. Jewett, president of the National Academy of Sciences and vice-president of the American Telephone and Telegraph Company. "Without insinuating anything as to guilt, the chemists declare that this is a physicist's war. With about equal justice one might say it is a mathematician's war."

It is clear that we require an all-out scientific effort. There are those who believe that we should have a military institute or institutes devoted to fundamental scientific research *without special objectives*. We already have at Aberdeen and Dahlgren and in the Office of Scientific Research and Development institutions working on special objectives. Those who advocate such new institutes feel that work done under pressure is not apt to be as profound as work more freely undertaken. The history of military invention shows how little one can predict the sources of inventions likely to be useful in war. My colleague, Edward Mead Earle, an authority on military history, writes as follows:

> Practically all basic inventions affecting naval, military, and aviation technology have been civilian in origin (as witness the rifle with interchangeable parts, the submarine, the machine gun, the tank, the airplane, poison gas, sound detection devices for submarines and airplanes, and most of the metallurgical discoveries which have affected armor and armor-piercing devices). The adaptation of many of these inventions to purely military purposes has, of course, been partly the work of civilians and partly the work of uniformed specialists.

In this connection I wish to describe an interesting example of a discovery by way of mathematical theory. An industrial firm was required to make a scientific instrument necessary for the prosecution of the war. Several models were known to the engineers in the blue-print stage, but it was not known whether any one of the models would be adequate or which one was the best. Considerable expense was incurred in building these models. The test was inconclusive. As a last resort a mathematician of note who was also an engineer was called in. In two weeks this mathematician had derived a mathematical theory of such models that said in effect, "Such and such models and only such models are possible, and type X is the best." This mathematical solution was complete and trivial in cost.

One can not generalize from one example, but it is becoming increasingly clear that an all-out effort will not draw the line too sharply between pure and applied mathematics. Oftentimes the difference between pure and applied mathematics is merely a matter of terminology. In papers in pure mathematics on the calculus of variations, for example, one can find principles, which appear in special cases in engineering books in the guise of the Ritz method or the method of the physicist, J. J. Thompson. Mathematical talent and engineering talent are neither interchangeable nor mutually inclusive. The only safe way in the present emergency is to use both to the maximum. In this direction lies the greatest strength, both actual and potential.

In Washington the Roster of Scientific and Specialized Personnel has registered tens of thousands of our scientists and technicians. Its officials are keenly aware of the importance of the proper use of scientific men. The Roster acts in an advisory capacity to the Selective Service Headquarters, reporting on shortages in various fields of intellectual work, and on the relative necessity of a man in his scientific occupation. It also makes recommendations to the Adjutant General's Office as to the use of young scientists whose induction has been ordered. To formulate policies on the

use of scientific and specialized personnel a national committee (under the chairmanship of Owen D. Young) is now at work.

I shall now turn to education and particularly to education in mathematics in its relation to the various training programs. We have available rather precise descriptions of the kind of training needed for college men who wish to enter the Signal or Air Corps of the Army or the Navy. Of these training programs that for the Signal Corps is perhaps the most technical. Officer material must have training practically equivalent to that of an electrical engineer. Needless to say, training in mathematics is fundamental and must include the calculus.

I have before me a pamphlet issued on March 1 of this year by the Navy and concerned with "Information for Institutions of Higher Education as to Class V-1 U. S. N." The introductory statement of objective is as follows:

> With a view to further expansion of procurement and training of prospective naval reserve officers, the Secretary of the Navy has approved the enlistment in the Naval Reserve of young men enrolled in accredited colleges, who, after enlistment in the Naval Reserve, may continue in college at their own expense, and in addition, be given naval training in an inactive naval status.

Under this program college freshmen or sophomores who meet the ordinary physical and educational requirements may enlist in the Naval Reserve and pursue the course V-1 for the first two years of their college course. I quote: "The pre-induction Naval training curricula will be prepared by the faculty of any accredited college which desires to participate in this plan and will conform to the normal program of that college provided it stresses physical training, mathematics and the physical sciences." The specific skills desired by the Navy are stated to be the following:

> (a) Skill in swift, accurate mathematical computation, and in the solution of problems of elementary algebra, plane geometry and plane trigonometry;
> (b) Skill in handling problems of general college physics; covering mechanics of solids, fluids and gases; light; and more fully heat, sound and electricity and their applications.
> (c) Good health and hard physical condition, the ability to swim, and the capacity for endurance of physical strain over extended periods. . . .

Students who satisfactorily complete the first two years' program may continue their college courses either in V-5 or V-7. In V-5, aviation cadet training is given and in V-7 the training is for midshipmen.

We turn now to the army aviation program with its proposed force of 2,000,000 men. Every bombing plane must contain at least one navigator. The problem of navigating a plane among the islands of the Pacific is very difficult. It is possible to lose as many men by faulty navigation as through enemy fire. It is clear that we must have tens of thousands of navigators. Are our students ready for this task? The answer is not one of credit to secondary school administration and policy. I am happy to say that the schools of New York, however, have performed their duty in a way that provokes admiration. But the same praise can not be given to all sections of the country. Fortunately, we have a disinterested appraisal of the situation from the pen of no less an authority than Admiral Nimitz, our Naval Commander in the Pacific. It is in the form of a letter written to an official of the University of Michigan. The letter of inquiry is written to Captain Lake of the Bureau of Navigation at the time when Admiral Nimitz was still the head of this Bureau. The letter follows:

> CAPTAIN F. U. LAKE
> HEAD OF THE TRAINING DIVISION,
> BUREAU OF NAVIGATION, WASHINGTON, D. C.
> MY DEAR CAPTAIN LAKE:
>
> When Admiral Nimitz visited the campus of the University of Michigan the other day, he

mentioned that there had been some difficulty in finding students in American colleges other than engineering who were sufficiently prepared in mathematics to make them available for training for commissions in the Navy. This situation ought to be called to the attention of educators in colleges and secondary schools throughout the country. I should deeply appreciate receiving a statement from you on this matter, especially if you could give me such facts and figures as would constitute a self-evident argument. I hope also that it will not be necessary to set any restrictions on the use of such information. It seems to me that educators should promptly recognize the danger, if there is any, from our past softening of our educational programs.

Very truly yours,
LOUIS I. BREDVOLD,
Member of the University Advisory Committee on Military Affairs.

The answer written by Admiral Nimitz follows:

MY DEAR PROFESSOR BREDVOLD:

Thank you for your letter of October 30. While we have not felt that it was our business to compile exhaustive data on our observations of the products of the educational systems of this country, we are in a position to give you some information on this subject.

A carefully prepared selective examination was given to 4,200 entering freshmen at 27 of the leading universities and colleges of the United States. Sixty-eight per cent. of the men taking this examination were unable to pass the arithmetical reasoning test. Sixty-two per cent. failed the whole test, which included also arithmetical combinations, vocabulary, and spatial relations. The majority of failures were not merely borderline, but were far below passing grade. Of the 4,200 entering freshmen who wished to enter the Naval Reserve Officers' Training Corps, only 10 per cent. had already taken elementary trigonometry in the high schools from which they had graduated. Only 23 per cent. of the 4,200 had taken more than one and a half years of mathematics in high school.

This same lack of fundamental education presented and continues to present a major obstacle in the selection and training of midshipmen for commissioning as ensigns, V–7. Of 8,000 applicants—all college graduates—some 3,000 had to be rejected because they had had no mathematics or insufficient mathematics at college nor had they ever taken plane trigonometry. Almost 40 per cent. of the college graduates applying for commissioning had not in the course of their education taken this essential mathematics course.

The experience which the Navy has had in attempting to teach navigation in the Naval Reserve Officers' Training Corps Units and in the Naval Reserve Midshipmen Training Program (V–7) indicates that 75 per cent. of the failures in the study of navigation must be attributed to the lack of adequate knowledge of mathematics. Since mathematics is also necessary in fire control and in many other vital branches of the naval officer's profession, it can readily be understood that a candidate for training for a commission in the Naval Reserve can not be regarded as good material unless he has taken sufficient mathematics.

The Navy depends for its efficiency upon trained men. The men are trained at schools conducted for this purpose and the admission of men to these schools is based upon the meeting of certain carefully established requirements. However, in order to enroll the necessary number of men in the training schools, it was found necessary at one of the training stations to lower the standards in 50 per cent. of the admissions. This necessity is attributed to a deficiency in the early educations of the men involved. The requirements had to be lowered in the field of arithmetical attainment. Relative to the results obtained in the General Classification Test, the lowest category of achievement was arithmetic.

A study has been made of the grades received in the examinations of candidates for enlistment in the Navy, classified geographically according to the location of the recruiting station through which the candidates applied for enlistment. It is to be noted that the proficiency in arithmetic in the eastern part of the country was strikingly greater than that of the middle west and west. The lowest average mark east of the Mississippi was equal to the highest average mark west of the Mississippi. The three highest average attainments in arithmetic were achieved by the recruiting stations in Troy, Brooklyn, and Buffalo—all in New York State.

May I express the hope that this information will be of assistance to you.

Sincerely yours,
C. W. NIMITZ, (Signed) F. U. LAKE,
Chief of Bureau By direction

The Bureau of Cooperation of the University of Michigan comments as follows:

When secondary schools eliminate not only trigonometry but also algebra and geometry from their programs, and then most of the reasoning problems of arithmetic, since pupils say they are too difficult, and offer as substi-

tutes general mathematics in the ninth grade, social mathematics in the tenth grade, and review of arithmetic in the eleventh or twelfth grade as the total mathematical program of the school, where along the educational ladder are pupils to obtain experience in reasoning and in practice in solving progressively more difficult mathematical problems? Where in the course of the four years are youth to find mathematical problems which will extend their intellectual horizons and stretch their mental muscles?

It is clearly not the fault of the teachers of mathematics that this situation has arisen except in so far as they have failed to convince school administrators and politicians of the importance of their subject. Where they have been allowed to teach mathematics in sufficient amount and where students have been encouraged to study mathematics the results in general have been reasonably successful. We are concerned here with a problem of public and community education to which I shall return later.

Our mathematical societies have been conscious of these problems for some time. One of the most effective of the subcommittees of the War Preparedness Committee of the American Mathematical Society and Mathematical Association of America is its Subcommittee on Education for Service. In the most recent *Bulletin* of the American Council on Education, No. 23, a statement is made that analyses should be made from the "training" and field "manuals" written by the armed forces to determine specific course content intended to provide background for later vocational training in the Army. Our subcommittee initiated such an analysis in so far as mathematics was concerned over two years ago and published its report over a year ago. This report has been sent to 5,000 secondary schools.

More recently, at the suggestion of officials of the Army Air Corps, on the nomination of the American Association for the Advancement of Science, a committee composed of the mathematicians Hart and Whyburn and the astronomer Wylie was appointed by the War Department with the following order:

To make a survey of the ground school courses offered in pilot and non-pilot courses in the Air Corps Flying Training System with a view to outlining preparatory courses to be offered in colleges and universities.

I quote from the committee's report to the War Preparedness Committee:

The committee carried out its investigations at various schools of the Air Corps in Alabama and Georgia during a ten-day period in January, and the confidential report of the committee was presented to the Chief of the Air Corps. In the report, recommendations were made concerning the content of a pre-training program for aviation cadets. These recommendations were accepted in full and are incorporated in the enclosed letter which has just been issued by Major General Yount, commanding officer of the Army Air Corps Flying Training Command. Copies of his letter will be sent to the presidents of all colleges in the United States and to various categories of administrators in the secondary schools.

It is logical and commendable that the Air Corps should request schools and colleges to emphasize the specified pre-training for aviation cadets, even though various cogent reasons make it appear unwise to *require* all cadets to obtain such training.

I shall quote one paragraph from General Yount's letter. It is entitled "Pre-training through Regular High School and College Courses":

If time limitations permit, it is recommended that a student get his pre-training through regular high-school and college courses, including the following: advanced high-school algebra; at least twenty-five lessons in solid geometry including the geometry of the sphere; plane and spherical trigonometry; descriptive astronomy; a college course in general physics; a course including a substantial amount of cartography. Additional courses in mathematics and the physical sciences would be useful for particular objectives within the Air Corps. It should be noticed that many of the courses in the preceding program can be taken in high school.

The letter continues with a detailed account of the number of hours recommended in mathematics, astronomy, maps, physics, etc.

Before I leave this subject of techni-

cal training, I shall add one word directed to the women. There is much that can be done to prepare women students to be useful. I do not have time to go into this, but I recommend that they write to the American Council on Education, 744 Jackson Place, Washington, D. C., for its February *Bulletin* No. 22, which gives a "Report of the Committee on Women in College and Defense."

Finally, I wish to comment briefly on the need for education for freedom and democracy, both now and after the war, and on the relation of mathematics to such education.

The attention which mathematics is now receiving and its great usefulness as a technical aid in war works both to its advantage and disadvantage. When the war is over and guns and bomb sights can be forgotten, what will happen to mathematics? Men will turn to social and humane studies and to the arts and philosophy. Unless mathematics is somehow associated with the humane studies and with philosophy, its greatest values will be obscured and forgotten. It will be back where it was before this war.

The answer is simple, but the implications of the answer as to courses of action are far from simple. Mathematicians must make it clear to their students that mathematics is an essential factor in cultural integration, that its history, together with that of science in general, is most relevant to the growth of freedom, that without an understanding of mathematics one can not really understand philosophy, that mathematics is an art as well as a science and that since the time of Plato mathematicians have valued it as such. They must not leave it exclusively to the humanists and philosophers to integrate the knowledge of the day and give it spiritual unity.

Recently I read a series of addresses on "Liberal Education and Democracy" appearing in the *Bulletin* of the Association of American Colleges.[1] The points of view presented by some of the speakers left me apprehensive. The speakers were not hostile to mathematics; mathematics was even emphasized, but frequently for erroneous or insufficient reasons. One of the contributors writes as follows:

> Each of the traditional liberal disciplines has an essential contribution to make to a liberal education—pure mathematics with its unparalleled precision; the natural sciences, with their amazing technique for objective thinking in the world of physical fact; the social studies for the understanding they give us of man in society; the arts and literatures for their beauty and their moral and religious insights; history and philosophy for their cultural integration.

I quote again "pure mathematics with its unparalleled precision." Yet who wants to be precise except on occasion? To give play to the imagination, to create and form ideas, to have a mastery of language and logic, to have that freedom that comes from recognition of dogma, and the open acceptance or rejection of an axiom at will, to recognize how much one does not know, or can not know; these things are all in mathematics. It is true that history and philosophy give us cultural integration, but only when the history includes the history of ideas, and when the philosophy comprehends the insights of mathematics. Mathematicians can not expect their colleagues, the humanists and philosophers, to be broader than they are willing to be. They must share the burden of cultural integration. More Whiteheads and Sartons are needed.

[1] *Bulletin of Association of American Colleges*, Vol. 27, p. 50.

THE CHEMISTRY OF TIME

By Dr. HUDSON HOAGLAND

PROFESSOR OF GENERAL PHYSIOLOGY, CLARK UNIVERSITY

I

MOST of us have wished, at one time or another, that we could return to earth a generation, a century or a millennium after death to see what it is going to be like. Some of us may just want to know whom our grandchildren will marry, while others are curious about the future adventures of mankind.

Many years ago H. G. Wells wrote a delightful story called "The Time Machine," in which a man invented a device enabling him to travel into the past or into the future along the time dimension while remaining stationary in space. In his story Wells has his time traveler say, "There is no difference between time and any of the three dimensions of space, except that our consciousness moves along it." But, as sensible people, we usually dismiss as the purest fancy the thought that time is something to be tampered with. By its very nature it seems to be the most unyielding aspect of our environment. Events are said to be as sure as "death and taxes." There is an objective, inexorable character to the irreversible march of time. "Time," according to Sir James Jeans, "does not cease to unfold itself at a uniform and uncontrollable rate which is the same for each one of us." It is just this view of time with which I propose to disagree, despite that fact that it seems to be an intuitive aspect of experience. I shall try to show that time is not a mysterious river flowing relentlessly on to eternity, but rather a system of relations subject to some degree of control. We shall see that there is nothing about time itself that prevents our speeding it up and slowing it down. In fact, experiments have been done which actually involve the practical projection of living organisms forward into the future.

II

We all possess a private, internal appreciation of time. We can gauge within limits equal intervals of the experience we call duration. Even asleep, our time sense continues to function. It is possible for many persons to waken themselves at predesignated times to within a few minutes after a night's sleep. However, our private time is not precise enough to serve the needs of society, and so man has measured time in terms of sharable recurring happenings, such as seasonal changes, lunar cycles and, best of all, the earth's rotation on its axis which he has divided into units of equal length—hours, minutes and seconds. With such a time scale as a standard, he has constructed mechanical clocks, and learned to standardize his internal time sense with his widely accepted time conventions.

Our public time is thus determined by relations of changing physical objects. It is meaningless except in terms of these relations. If the universe were really to run down so that all motion, including molecular motion, were to stop, time, it appears by any meaningful definition, must also stop, outlandish as this view is.

Since clock time depends on relative motion, let us ask ourselves what is the source of motion determining our private or psychophysiological time? We judge time with our brain. To keep our brain cells functioning they must continually burn foodstuffs. This burning or oxidation is dependent upon motions of molecules, as are all chemical processes. A series of experiments has shown

that our judgment of time depends on the speed of these processes.

Most chemical processes are known to be roughly doubled or trebled in speed for a temperature rise of 10 degrees Centigrade (18° F).[1] If private, psychophysiological time is determined by chemical velocities, raising our internal body temperatures (as might occur in a fever) should speed the reactions, thus making more chemical change and hence more physiological time pass in a given interval of clock time than would normally be the case. If, let us say, two minutes of private, subjective time were thus to pass in one minute of clock time we would think that time was dragging; on looking at the clock it would be slower than we think it should be. Lowering the internal body temperature, on the other hand, should have an opposite effect, making clock time seem to pass faster, since the reduced biochemical changes would make less time seem to have passed and our public clock would, in contrast, appear to run faster. In a fever, *other things being equal,* we should come early for our appointments, and at subnormal temperatures we should come late.

I outlined these questions about time to myself on the first occasion in 1932, when my wife fell ill with influenza and developed a temperature one afternoon of nearly 104° F. She had asked me to do an errand at the drug store and, although I was gone for only twenty minutes, she insisted that I must have been away much longer. Since she is a patient lady, this immediately set me to thinking along the lines just indicated and then hurrying to find a stopwatch. I then asked my wife to count to sixty at a speed she believed to be one per second without telling her why. As a trained musician she has a good sense of short intervals. She repeated this count thirty or forty times in the course of her illness, her speed of counting was measured with the stopwatch, and her temperature was recorded each time. She unknowingly counted faster at higher than at lower temperatures. On the strength of this the experiment was repeated with several volunteer subjects given artificial fever by diathermy. I later discovered some data published earlier by a French worker, François, on the frequency of tapping a prescribed rhythm at different body temperatures. All these data, both those from Paris and from my own experiments, showed the same result as regards judgment of time. What is really significant, the data conformed exceedingly well to the mathematical relationship known as the Arrhenius equation, which describes the rates of chemical change with temperature. In fact, one of the specific chemical speed-temperature relationships, a constant in the equation that had been observed in several studies of the burning of foodstuffs by living cells, described the speed of counting. These results, published in 1933, were consistent with the view that our sense of duration, other things being equal, acts as if it were directly proportional to the speed of some internal chemical pacemaker.

At about the same time, and quite independently, Dr. Grabensburger in Austria showed that ants and bees taught to come for food at a particular time came earlier if the temperature in their experimental room was raised, and later if it was lower than that used for standard tests. This behavior is clearly quite in keeping with our findings in connection with the human time sense.

It is rather appalling to think of the kind of world we might live in if we did not possess a beautifully precise apparatus for keeping our internal body tem-

[1] On the Centigrade scale water boils at 100 degrees and freezes at zero degrees. This is in contrast to the Fahrenheit scale on which water boils at 212 degrees and freezes at +32 degrees. One degree Fahrenheit is 5/9 degrees Centigrade. Temperatures below the zero points on the respective scales are referred to as negative or minus temperatures.

perature constant. All animals, other than birds and mammals, lack this thermostat for regulating their internal temperatures. To such animals a linear time scale such as we have adopted as our public standard would be meaningless. For a difference of 30° Centigrade (54° F) between summer and winter, time must pass for the so-called "cold-blooded" animals[2]—frogs, reptiles, insects, etc.—roughly ten times as fast in winter as it does in summer. What kind of public time standard would we have devised if we lived in a world with a time warp of this order of magnitude? If an hour in a warm house corresponded to sixty subjective minutes, an hour out-of-doors on a winter's day would seem to us six minutes long! Public time-keeping without our physiological thermostats would indeed be a problem.

With our physiological thermostats permitting normal *internal* temperature fluctuations of less than a half-degree Fahrenheit around a mean of 98.6° F (37.0° C) the steady-state chemical events give us a linear, private time scale which we can standardize against our objective clocks. Biological oxidations, proceeding at a relatively constant speed, furnish us with a basis for our uniformly flowing time scale.

If our time sense depends primarily on biological oxidations we might expect that a variety of factors other than temperature would modify it. In recent years it has been shown by Sterzinger and Buchler that thyroid extract, known to speed biological oxidation, effects the time sense in the same general direction as raising the temperature, *i.e.*, public clock time appears to drag in contrast to our speeded "chemical clock." Quinine, which slows cellular oxidations, has the opposite effect. These relations had also been established earlier for the time sense in ants by Grabensburger. In acute emotional disturbances it is said that time seems to pass very slowly—the drowning man sees his life pass in review. Is this because of accelerated oxidations somewhere in the brain? In general, however, activity makes time appear to pass fast in contrast to the boredom of waiting and inactivity. Does this mean that there is a part of our brain concerned with the estimation of time that has its metabolism slowed during the general enhancement of activity by other parts of the brain? We simply do not know the answers to these questions as yet.

Our views about time are consistent with a number of older experiments. The concept of physiological time is by no means new. Aging is the result of a complex series of chemical changes. Jacques Loeb and others demonstrated long ago that fruit-flies and other so-called "cold-blooded" animals live longer the lower the temperature at which they are kept; du Noüy has demonstrated quantitatively that wounds heal progressively more slowly the older one is. For example, if a child of ten years heals over a wound of a given area in 20 days, a man of 20 will require 31 days to heal over a wound of the same area; a man of 30 will require 41 days, a man of 50 will require 78 days and a man of 60 will require 100 days.

It is common observation that time to the young passes much more slowly than it does in old age. A year to a man of 50 seems very short compared to a year at age 10. It has been established that metabolic processes in general become progressively slower with advancing years. This might make time seem to pass faster in old age, as indeed it does.

III

I wish now to suggest what may appear to be a bizarre proposition. It is that one can, for all practical purposes, construct a "time machine," making possible

[2] Such animals are, of course, not necessarily "cold-blooded." They are animals that do not regulate their internal body temperatures at a fixed level. Their blood is at the same temperature as their surroundings.

travel for living organisms forward into the future, although not backward into the past. This proposition is inherent in the essential nature of time, as outlined above.

One aspect of the relations between temperature and the speed of chemical reactions is that the curves describing these relations all take origin from the absolute zero of minus 273° C. At this temperature all molecular thermal motion ceases. The element helium, a light gas at ordinary temperatures, becomes a liquid at a temperature of minus 270° C (minus 518° F), and experimentally liquid helium has been cooled even a degree or so below its very low boiling point, but the absolute zero has as yet not been reached in the laboratory. Now, as we mentioned, the aging of living organisms is the direct result of a series of chemical changes. If organisms are exposed to lowered temperatures their aging is slowed. At the temperature of liquid helium, for example, rates of aging processes should be stopped or should proceed at an infinitesimally slow rate as compared to those at our body temperatures. If in some way it were possible greatly to lower the temperature of organisms so as not to produce irreversible and lethal changes and then later to raise the temperature again, the organisms would, for all practical purposes, be projected forward into the future during the time they were exposed to the very low temperature. Clock time for them would pass almost infinitely fast, while public time for the rest of us would proceed on at a constant rate. If such organisms possessed anything like memory resulting from the physico-chemical organization of their nervous systems, this, too, would be held in abeyance on cooling and started again on warming with no intermediate awareness of the lapse.

At this point you may be thinking that this is all rather amusing, but what of it? Living organisms in general readily freeze to death, and mammals like ourselves soon die if our internal body temperature falls even as little as 15°–20° F for a period of a few hours. But is it always necessary for cells to freeze when the temperature falls to very low values? Freezing is crystallization by definition. If heat is removed sufficiently fast from substances that normally freeze at definite temperatures they do not have time to crystallize, but instead pass directly into a different kind of solid condition known as the vitreous or glassy state. Such glassy or vitrified substances if slowly warmed will crystallize, *i.e.*, freeze. If they are very rapidly warmed through the temperature range in the vicinity of their normal freezing points they may pass directly from the vitreous to the liquid states. Pure water is hard to vitrify, since its speed of ice crystal formation is so very rapid. But watery solutions of substances composed of large molecules which are referred to as colloidal solutions are more readily vitrified. The large molecules of the substance in solution interfere with the ice formation. Thin films of gelatin solutions, for example, may be vitrified if plunged from room temperature into liquid air at minus 200° C. The films must be thin enough to permit a drop of temperature inside them of approximately 200 degrees per second, since otherwise the water will crystallize and not vitrify. We are indebted to Professor B. J. Luyet, of St. Louis University, for valuable contributions to this field of research and for applications of these ideas to the vitrification of living tissues which, after all, are complex colloidal solutions.

A number of workers, for one reason or another, have experimented with life at low temperatures. As early as 1893 R. Pictet showed that certain bacteria and protozoa could be revived after exposures to the low temperature of liquid

air. *W. Stiles, in 1930, reasoned that rapid cooling might produce a reversible* state of suspended animation by the avoidance of ice formation. Professor Luyet and others had made a number of interesting contributions, and late in 1940 Luyet and Gehenio published a book on the subject of "Life and Death at Low Temperatures." They presented experimental evidence indicating that below critical temperatures the vitreous state of certain colloidal solutions will remain indefinitely, there being no tendency to pass over into the crystalline state. These temperatures for colloidal solutions and for some protoplasmic systems, which are, of course, colloidal in nature, extend for only some 20 to 30 degrees below zero on the Centigrade scale (77° to 86° below zero Fahrenheit). The literature they cite shows that a great variety of organisms can survive very rapid cooling in the liquefied gases and subsequent rapid warming. Moreover, the length of time endured in the vitrified state, as we should expect, in most cases seems to have no effect on the percentage of organisms reviving. Upwards of 120 investigations have demonstrated vitrification and revival of many forms of plant cells, of many forms of bacteria, of a number of forms of protozoa and of certain small metazoans. Luyet and Hodapp were able to vitrify and revive the male reproductive sperm cells of frogs, and Dr. L. B. Shettles in 1940 has done the same thing for human sperm, obtaining a few per cent. revival after immersion in the liquefied gases.

The organisms withstanding this treatment must be small, since if they exceed more than a few hundredths of an inch in thickness they are likely to vitrify on the outside and freeze on the inside, thus producing death. Organisms with low water content also are, in general, more likely to survive the treatment than are those with a high water content. The *main thing apparently that prevents the projection of a living contemporary human being into the future to accompany* the "Time Capsule," buried at the site of the New York World's Fair, on its journey to 6940 A.D. is the fact that minus 270° C, the temperature of liquid helium, is not a great enough temperature drop from that of his body at 37° C to allow him to be vitrified throughout in less than one second, a condition necessary for tissue survival. This limited temperature range of 307° C (*i.e.*, from minus 270° to plus 37° C, the temperature of his body), his size and the high specific heat of water of which he is primarily composed, evidently precludes him from this interesting journey into the future along the time dimension. It would also be a prohibitively difficult task to keep him refrigerated for 5,000 years, although he would probably be safe in storage at 30° below zero Centigrade, since, according to Luyet, this is below the crystallization or freezing temperature of vitrified protoplasmic systems. Reviving him would conceivably be slightly less of a problem, since he could be dunked in a measured weight of warming liquid at high temperature and of known specific heat so that his temperature would rise rapidly as the bath's temperature falls and the two could be calculated to come to rapid equilibrium at 37° C, his normal body temperature. Such a hypothetical man should arrive with the Time Capsule at 6940 A.D. ready to interpret its contents to the "Futurians," no older than when he started his journey, since all his biochemical processes, including those involved in mental functions would have been fixed safely in the vitrified tissues.

While, for purely physical reasons, we clearly can not send a man on such a journey, we might just possibly be able to send his immediate son. During the past year Dr. Gregory Pincus and I have confirmed Shettles' finding that

human sperm can survive immersion in liquid nitrogen at minus 195° C (minus 383° F). Moreover, by technical improvements and pretreatments of the sperm we have increased the survival number from a few per cent. to 50 per cent., a concentration of sperm sufficient to insure easy fertilization of human ova. The revived sperm are just as vigorously motile as are those untreated and there is no reason to suppose that their fertilizing powers are impaired. Curiously enough, human sperm are much more resistant to this sort of treatment than are those of other mammals we have studied, which include rabbit, guinea pig, rat, mouse and bull. Luyet was unable to revive rat sperm after his successful experiments with those from frog. By special pretreatments we have been able to obtain from one half to one per cent. of live rabbit and bull sperm after immersion in liquid nitrogen. It is, of course, imperative now to get the revived sperm of experimental animals in appreciable yields so that we may test their fertilizing ability.

Vitrified sperm may deteriorate with time. We should not expect them to do so, but only further experiments can confirm our expectation that vitrified sperm will remain viable indefinitely. Shettles kept samples of human sperm at minus 79° C (minus 142° F, the temperature of "dry ice") up to 70 days. His data show a small decrease in the number surviving 70 days at this temperature compared to the number surviving a few minutes. But with his small yields and with the wide variability in samples showing these low yields of recoverable live sperm, we do not regard this apparent trend in a few experiments as especially significant.[3]

The problem of keeping sperm in suspended animation may be a very practical one for animal husbandry. The indefinite storage of the sperm of prize animals and their possible use to renew prize stock after it has degenerated by faulty breeding is at once apparent. A great horse like "Man O'War" could thus have immediate sons many generations after his death. It is even conceivable that at some time in the future we may systematically draw upon great geniuses of the past to father our human offspring. Possibly institutions which now store the memorabilia of our great departed may one day also store their vitrified sperm. Married couples today, when the husband is sterile, sometimes have children by sperm selected by their physician from a donor known to him but forever unknown to the couple. Social sanctions may ultimately extend this practice to illustrious men of the past not only for the fertile wives of sterile couples but for certain other women as well, especially since emotional revulsion might be reduced in the case of a non-contemporary donor long since dead. The historical test of genius would have operated so that part of each generation could be fathered by truly great sires.

While it still remains to be proved that vitrified sperm will keep indefinitely with fertilizing powers unimpaired, one is tempted with a variety of speculations. In a world rent by war and strife, the physically best are, in practice, selected for the most dangerous service. The possibility of the storage of vitrified and revivable human sperm available in the event of the donor's death may, at some future time, have considerable social significance.

[3] Since writing the above, Dr. Pincus and I have stored human sperm in dry ice, removing samples from time to time to test their motility. All samples thus tested over a span of 125 days have shown no decline during this time in the percentage of sperm revival compared to the percentage revivable immediately after vitrification.

WHAT ARE THE FITTEST?

II. WAR THROUGH THE GLASSES OF A BIOLOGIST

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The present application. In the first part of this article we have inquired into the origin of the concept of inevitable natural selection in an inescapable struggle for existence, a concept to which the term "survival of the fittest" was soon applied by a philosopher. We have tried to show how, in the minds of some philosophers, historians and international politicians, and doubtless in the minds of some biologists, the meaning of these words so shifted that the phrase came to signify a concept very different from the original. We saw that this interpretation of the survival of the fittest even became the foundation stone of national and international policies. The substituted concept of triumphant might was not new; the deadly national policies based upon it were not new; but the presumption that the policies had a sound and compelling biological basis, besides a historical basis, was relatively new—and it was also fallacious, as regards the alleged biological basis. This particular biological writer was even presumptuous enough to question the historical basis, which seemed to derive from the failure to look squarely at the whole picture. He made no claim to proficiency in the study of history; but, after all, history and sociology have their biological aspects and a biologist may be justified in remarking that it simply does not make sense to assume that social progress and empire-building have rested primarily upon an alleged "biological principle" that is too easily discredited. Narrowly selfish aggression, subjugation and mutual exploitation are not wanting from the pictures of past or present human lives; but if they, rather than the more obvious biological principles of cooperation and social interdependence, have indeed played the greater part in leading mankind at different times from savagery to high levels of culture with its idealism and respect for honorable and charitable human relations, then biology, the *science of life,* has nothing to offer to human *life*—and this is a contradiction in terms.

In the part that follows, I shall try to write as a biologist undertaking an objective view of his own species in the setting of the organic world, with full recognition of the inevitable limitations of view for one who has concentrated his attention upon certain parts and aspects of that world. It happens that uppermost in our minds at the present time is a military conflict of unprecedented scope and violence in which virtually the whole human race is directly or indirectly involved. In all the history, human or biological, of which we have any knowledge, there is no record of either an intra-specific or inter-specific battle for survival of comparably world-wide extent. In its scale, it is definitely something "new under the sun"!

If we take the present world-wide conflict as a social or biological problem and attempt to follow the solution along biological grounds, we start, as in the solution of all problems, with certain assumptions. Our first assumption is that the dominating strength of cooperative effort has been abundantly demonstrated in biology and history. We should like to take as our assumption of the second order that one side in this struggle, our

side, represents the spirit of cooperation and the other that of exploitation. With such assumptions of the second order offering a clear issue between sheer military power and the cooperative support of liberty and order, events up to the present time would seem clearly to favor the success of the former. We might be tempted to say the other side was right and we were wrong. Certainly we have had no choice but to accept the challenge of aggressive military power; we must seem to adopt the dogmas of military might; we must engage in a war of annihilation, it is only fair to say. Are we, then, to lose faith in our expressed ideal of cooperative orderliness in the light of the apparent evidence of its ineffectiveness and of our own now wholehearted and inescapable expression of the most violently aggressive spirit we can command?

The actual fact is that, regardless of *expressed* principles of action and ideals, the present issue can not be formulated as stated above. Those who proclaim the survival of the strongest actually assume, demand and receive the cooperation of enormous numbers of peoples of several nationalities; they have a highly developed social order. The cooperative spirit in the pursuit of a particular objective has perhaps never before been so fully and clearly exemplified as in Germany and Japan during the past decade or more. Their utter devotion to a common cause and their deadly earnestness in its furtherance can not fail to command our coldly intellectual approval. Of course, a defect in their exemplification of the ideal of social cooperation is that it stops at fixed national boundaries beyond which any cooperation must be one-sided and imposed upon others, beyond which the feature of mutuality is lost. Another possible defect in their exemplification of the cooperative spirit arises from its linkage with the conception that "might makes right." When outside enemies shall have been incapacitated for resistance, the winners may well lose the fruits of victory through unexpected application of their own theory within their own group. That would, however, be too late for our salvation.

What of the other side? Have those who have proclaimed most loudly the value of a better social order and of human cooperation, have they, ourselves and others, practiced any such mutual aid beyond their own national boundaries? There could be no question respecting our adherence to the ideals of cooperation, altruistic sympathy and mutual helpfulness, if lip service could be accepted as valid evidence. Would it not, however, be doing violence to the actualities if it should be said that during the past few years we have done anything in a practical and effective way to bring into the scope of our brotherhood of men the Chinese struggling valiantly for the right to live their own lives as adherents to the principles of peace and cooperation, the Poles, the Norwegians, the Czechs, the Belgians and a half dozen other peoples, to say nothing of the French, the British and our own good neighbors, the Canadians? Disregarding the trivial fringe who asked for peace at any price to ourselves, have we not generally demanded peace for ourselves at any price to every one else? Have we not as a nation been just as strict adherents to the faith in national interest and national superiority as have the Germans or the Japanese? These latter nations do at least include in their preaching, whether sincerely or not, the aim of promoting a more widely extended social order for the benefit of all, even if it does inevitably mean "we first." But we, too, know the slogan, "America first."

The avoidance of entangling alliances, doubtless an excellent doctrine in the time of its origination, has been one of our firmest articles of faith through all

the life of the republic. Self-sufficiency, self-interest and disregard of what might happen in the rest of the world and how it might affect us in the long run have been vital parts of our unwritten constitution, which has probably been preserved with greater integrity than has the written constitution. There may have been a few modifications represented, perhaps, by the Monroe Doctrine and the Spanish-American War; but, certainly during the past twenty-odd years, the isolationist and nationalistic policy has been more pronounced than ever before. As to the human race as a whole, our working principle of survival through cooperation has been as closely confined within our own boundaries as has that of any nation now our enemy. This is not a complaint but a bare statement of fact. To our credit let it be said that we have also kept our animosities within our national boundaries: we have not recently sought to conquer others.

But our blind concentration upon national interest, narrowly conceived, in contrast to world interest, or a broader conception of self-interest, is not the worst of it. What has been the internal situation? To what extent can we point with pride to any general willingness to sacrifice the interest of individuals and groups to a common interest? Again there has been lip service. No manufacturer would ask for a high protective tariff for his own personal enrichment, but rather for the benefit of American labor. Labor may have been a little more frank in demanding for themselves a higher share in the wealth produced by farming, mining and industry, but usually with no little emphasis upon the great benefit to the farmers and the miners of an increased purchasing power for industrial labor. Farmers have voted enthusiastically for subsidies and high farm prices. Some mining interests have worked for an artificial price for their product. I am not offering a word of criticism against any of these demands and efforts, nor expressing an opinion as to whether the several demands have been incumbent upon the respective groups *in the prevailing circumstances.* They are mentioned solely with the objective purpose of suggesting the desirability of a detached consideration of the question whether or not we have within our own boundaries manifested any high degree of internal adherence to the principle of mutual effort in the common interest. Personally I believe the answer is "No," but it is not necessary to argue the point. You may give any answer that seems justified by the facts; but it does seem clear that, if our present endangered situation has arisen in spite of substantial practical application of a national cooperative effort to serve best the good of all, the results up to now do not speak too well for the protective effectiveness of that spirit as it has been manifested during the past score of years. If we did not know before we ought to know now that it is hard to beat people who really work *together*—and really *work*.

We know of course very little in a direct way about internal cooperation in Germany and Japan, but we have a wealth of circumstantial evidence and, on the whole, it seems very clear that, if wholehearted cooperation and mutual aid within relatively narrow geographic boundaries can be the basis for survival, the Axis powers would have a very good case on their side. Most emphatically I do not assume that to be the case. Indeed the Axis powers have rendered a distinct philosophic service in reducing to an absurdity the idea that war is a means of effecting the survival of a superior kind of people. Who will be the victors—the supposed "survivors"? Whites? Yellows? Browns? They are on both sides, or may be. Teutons? Slavs? Mediterraneans? Caucasians?

Mongolians?, etc. There was never more scrambling of races in the armies of two sides in a war!

Obviously the conclusion is that, as a very large number of people have felt for a long time and perhaps many more in recent months, the world has so changed in respect to conditions of transportation and international communication that a nationalistic definition of cooperation and mutual aid is no longer sufficient, if indeed it ever was. Furthermore, the spread of education and communication and the wide extension of intra-group contacts and acquaintances, with development of group consciousness and recognition of group power, have resulted in a temporary state of increasing social disruption, not to say chaos, which is going to necessitate a much greater effort for consolidation than has yet appeared.

It should be obvious that cooperation and mutual effort toward a common end can be effectuated only under conditions of safety and order, and, as almost everywhere in the animal kingdom, safety and order can be attained only by the sacrifice of individual and small-group interests to those of a larger group. The real question confronting the human race at this time is—how broad shall be the group whose interest is to be paramount over the interest of individuals and of local or industrial groups? There is, I think, no difference in character in the answers given by different people and by different groups. The answer may be the industrial or the social class to which individuals pertain. The answer may be the State, that is to say, a particular State; the answer may be the aristocracy of birth or wealth; the answer may be the proletariat; the answer may be the hemisphere; the answer may be civilized man; or the answer may be mankind at large. The last answer seems to be that of Christianity, which has been widely extolled but never yet taken generally as politically practicable. Has it ever been the actual basis of national policy? The various "isms," so much to the front in recent years, seem *all* to have been satisfied with answers like the State or the Proletariat.

It may, then, be said that one answer to the question of why we face to-day such an overwhelming task is that we have not practiced in even half-way fashion, either among nations or within our own country, what we have preached with reference to mutual aid or social order, to say nothing of our past disregard of the frank scorn of our present enemies for our "naive" social philosophy and our deafness to their repeated bluff warnings. Neither radicals, liberals nor conservatives can put the full blame on others. What have been our national ideals? The so-called American standard of individual success through the mere attainment of wealth is now too generally discredited to justify consideration in this connection. What ideal has been most to the front but lives of ease for all, the chicken in every pot, two cars in every garage, a 40- or 30-hour week (for some, not for all), a soft life for every one, security without commensurate effort? We have sought a fool's paradise, than which there is nothing lovelier or more perilous. It is no disparagement of democratic ideals to admit that a people taught to believe that the State *must give them* security and comfort has some initial handicap in the acid test of conflict with peoples taught to believe that *they must give* security and power to the State.

Actuality of the struggle for existence. It is perhaps natural that biologists, impressed with the daily observation of "the struggle for existence" in the organic world, should be skeptical of the practicability of a general life of ease and security. Everywhere in nature we see such a struggle, and frequently on a

stupendous scale, as where millions are born for a pair that survive. We see everywhere in the animal and plant world the need for self-protection, for the maintenance of territorial areas and for resistance to external aggression. It is commonly accepted that "self-preservation is the first law of nature." We pass over for the present the fallacious politico-philosophical extension of this principle to justify aggression and subjugation. The extent of over-production, and that of the consequent culling, vary widely with different kinds of organisms. In one case, as just suggested, there may be millions produced for the tiniest fraction of one per cent. that survive. In another case a dozen or even less may be the measure of the biotic potential, with survival of eight to twenty per cent. I know of no case where a pair of organisms in nature normally give rise only to the number that survive, that is to say, of no species suffering no mortality from depredation, disease or starvation, exempt from necessary processes of elimination and free from interspecific competition for mere survival.

Parenthetically, it is true that, by some peoples, overcrowding has been advertised as an argument for wars for expansion of territory. It will be time to take seriously a complaint of overcrowding when those who broadcast to the outer world their pitiably congested conditions stop urging their own people to be more zealous and efficient in reproducing. It is not logically sound to promote a condition of overcrowding by producing greater crowds. Certainly it is not clear that the most populous countries are the most warlike, or that those who cry for expansion want space so much as power over others.

The mere preservation of life is not, however, the only feature of the struggle for existence. If I, as a biologist, can not envision a permanent state in which every able-bodied person loafs or plays most of the time when not asleep, the trouble may of course be in my capacity for social vision. There have been leisure classes and sometimes they have looked very nice. Perhaps at times most of us would like to belong to such a class. Has there ever been such a class that did not derive its living from the labors of others, and has there ever been any real service to mankind from the representatives of such classes, except as they have foregone leisure for genuinely hard work? Is anything worth doing easy to do? Was the shibboleth of "the strenuous life" a completely futile one? Is it not just possible that no one should loaf more than is actually necessary for the maintenance of physical and mental efficiency, except in so far as, for purely sentimental reasons, or for lack of assurance regarding the unforseeable potentialities of social contribution, we maintain the crippled and the aged? The immature need not be excepted, with the understanding that the "work" of children includes play and learning, which are necessary to the development of physical and mental efficiency and that it should also include a reasonable amount of useful social service as an essential part of the preparation for the physical, mental and moral responsibilities of complete citizenship. We are now told that we may have to live *hard* "for the *duration.*" That may be for the duration of the war, or it may be for the duration of the order which may follow the war—for the duration of time. We are beginning to forget that we have heard that we need not sacrifice our standards of living for the national emergency; rather, we are beginning, and doubtless merely beginning, to face just this sacrifice.

In a very real way social science is a branch of biology, but biology is a very broad field and no one can encompass the whole area. Perhaps it would be

better if social theorists knew more biology and biologists knew more social science. A laboratory biologist may not answer but perhaps he is justified in asking the questions: To what extent generally can a high standard of living, in the sense of ease and security, be indefinitely maintained without the erection of tariff barriers and other economic and political walls around our own section of the earth's surface? and: How can we maintain such barriers and still be full participants in a world-wide social order ensuring security against the rhythmic recurrence of world wars? It is an unpopular question, and possibly a dangerous one even to state, but is the progress or the virility of the human race capable of promotion by any general guarantee of ease and security? Certainly no State boasting of the effectiveness of its particular "ism" has offered anything like general individual ease and security, to say nothing of freedom! "Youth demands security," we were hearing quite recently; the demand might be all right, if you can give satisfactory answers to the questions: Of whom? and For what end? At any rate youth have definitely not gotten security! We used to hear: "He that saveth his life shall lose it!"

Doubtless it will be deemed irrelevant to point out that the pioneers in America and those of the Great West found no softness or security except as they got it in the hard way. What people have continued to enjoy for long a period of easy life? There is no inconsistency between an ideal of mutual helpfulness and an ideal of hard work and self-reliance. What man needs in social help is not a guarantee of security through the accident of having been born in a particular community or group or through the purchase or gift of a membership ticket, but a chance to fight his own battle, not with the sword or gun if avoidable, but with his own physical, mental and moral powers exerted in his own and the general social interest.

Prognosis. We have implied that, in the present time at least, wars are social disorders, which, if unchecked by the most vigorous and concerted action of those who prefer peace to warfare under modern conditions, actually threaten the preservation of the race in any tolerable state of culture. Is there a conceivable remedy?[1]

We do not ask if the present war could have been prevented. I may think it could have been obviated had we done thus and so; you may hold that enduring peace could have been assured by actions of the very opposite nature. Let us steer away from the treacherous rocks of futile argument about the past and set our sails with all hands alert to weather the reefs that lie straight ahead. We are in a desperate struggle: either we shall lose and have no say about the future order; or we shall win and have a voice in shaping the future. I do not happen to have confidence in winning without sacrificing our recently cherished way of life. Be that as it may, and, at the best,

[1] The outlawing of war is the reverse of the philosophy of "pacifism" in the special sense. We may all be pacifists in the sense of having an abhorrence of war; but I could never see the position of the pacifist, who would enjoy the results of the protection of homeland and family by others but would not participate in the disagreeable efforts involved in protection; who would enjoy the order of a community without giving aid to the police or being ready to take his full part in an emergency. It is a fine line to draw between the "conscientious objector" and the parasite. We do not recognize the conscientious objector to tax-paying, although he asks much less of a sacrifice of his fellows.

It may be noted here also that some intellectuals seem to see only a fine line of distinction between defensive and offensive wars; notwithstanding that our whole system of internal order is conditioned upon the recognized capacities of jurymen of average intelligence to see the difference between killing in self-defense or in maintenance of order and killing for aggrandizement of individual or group.

I do not now see the chance for an "American-made" order after the war. It requires more national complacency than I can justify in the actual circumstances to imagine that we can subordinate the parts to be played in the final settlement by the Chinese, the British and the Russians. We do look forward confidently to having a voice in the afterorder, and, let us hope, an equal voice with those who were driven earlier to fight for some freedom to shape their own lives.

The question to which we address ourselves now is: Is warfare for survival, inescapable as it is to-day, to be looked upon as a forever-recurring phase of human history? We have already expressed our definite opinion that it is not a normal biological phenomenon, that it is not necessarily ingrained in man. Without going back over the previous discussion, let us deal now with the argument that inter-tribal and international wars have marked all human history. This does not make warfare normal in the sense of being inherent and inescapable any more than are murder and rape, any more than is infanticide or slavery. There was real philosophy in the comment of the old cannibal chieftain, who, having listened with wonder to the story of a veteran explorer about the thousands killed in a battle between civilized armies, inquired skeptically: "But how could you eat so many?" When told that the killed were not eaten, he exclaimed: "Don't eat them! Then, why do you kill them?"[2] Imagine the task of convincing the cannibal that an age-long practice was not ingrained, inevitable and entirely proper!

If one other story may be interposed, it is that of the shoemaker whose oracular utterances commanded the respect of his neighbors. They sought his opinion regarding the prospects for recovery of an aged friend who was critically ill. Upon due deliberation the shoemaker prognosticated confidently that the man would recover. When pressed for his reasons, he replied with solemn assurance: "Well, he always has!" Have we not all something of the shoemaker's faith in the past?

[2] I wish I might credit this story to the real author, whose name I do not know.

We outlive some of our practices or we do not. Warfare has become a practice so expensive and so destructive, not to life alone, for only ten or twenty per cent. are killed, but to any form of tolerable social order, that we may have to outlive it or else succumb to it. It may not do any longer merely to hope that we can somewhat prolong the intervals between wars—to strive, as a friend recently proposed, to put off the next war for thirty instead of twenty years.

I was reading recently a contemporary account of the black plague that swept across Europe in the fourteenth century. In the one city of Florence the number believed to have died was greater than the number previously supposed to have lived there. At least ten million, or about seventeen per cent. of the population of Europe, are supposed to have died (Pearl, 1939, p. 308). Everywhere there were demoralization and disruption of established modes of social life. Explanations of this continental catastrophe were not wanting. Wearied of the wickedness of his terrestrial subjects, the Almighty had sent this devastating visitation to wipe out the majority and make a fresh start; or it was attributable to the unfortunate operations of the heavenly bodies. One might have argued in vain that, although doubtless the plague was unavoidable as an initial localized outbreak, yet proper knowledge, determination and effort could have effected control—as we now know. Had we lived at that time, the plague would have seemed one of the inevitabilities. It had always been liable to occur. Who could govern the action of the Almighty or direct the movements of the stars? We could only have hoped that

it might be a long time before the next recurrence. There may be here a closer parallel than we are likely to imagine between the old fatalistic view of disease and the present concept of the inevitability of war. If only fifty odd years ago you had been with de Lesseps in Panama and had argued that malaria and yellow fever were not inherent in the situation and had prophesied that within twenty years the Canal Zone would be one of the healthiest places in the world, you would have been in danger of committal to an institution for the feeble-minded. Nevertheless, your prophecy would have been gloriously justified on schedule time. Science pointed the way, and Government took intelligent and effective action.

The future peace will, I feel sure, rest upon power and concert of power, without necessary equality of power, rather than upon adjustment and compromise. I am well aware that many social and political idealists will dissent when it is predicted that peace will not be based upon compact with the vanquished (it will not be if the other side wins!). It will not rest upon compromise or compact. It is a question of one's concept of the real nature of war. If one palliates offensive war one may expect a temporary peace. Undoubtedly there have been times in the past, when battles to the death between men and armies were looked upon as merely a particularly rough form of sport. It is not so now. Perhaps conditions have just changed; but the Germans and the Japanese sensed the change first. They have eliminated the aspect of sportsmanship; the principles, or "unprinciples," of gangsterism offer greater advantages. If offensive war is to be totally rejected as an instrument of national policy, if it is to be regarded as murder, arson and robbery on a grand scale, the perpetuators will not find themselves on an equal footing in the post-war order or deem it safe to plan for another. Take this opinion or leave it: if you know a better way to deal with national egotism in the nth degree, empowered with the scruples of gangsters, we should all listen, of course.

I do not yield to the defeatism that contemplates periodic wars because man is built that way. "There shall be no end to war in this world," we were told about 2,000 years ago; but we had always had plagues, and we do not now think of them as beyond control. We have heard that war is necessary to the virility of a people; but no evidence has been adduced to support an apparently specious contention: how can the race be improved by the elimination of the most virile? Wars are necessary to relieve overcrowding; but war is followed by an increase in birthrate, and not necessarily for the sturdiest. Wars are the inevitable results of economic strains; but what economic improvement can be effected by modern war? Wars are even less useful than the plague, but we do not palliate bubonic or yellow fever. To be sure, future wars will not be estopped by wishful thinking or talking; adequate organization supported by effective power is the desideratum. No doubt the power will have to be mundane in scope; the time for a pax Romana, a pax Britannica, a pax Americana or any other imperial pax, is probably gone. We may look forward to a "pax mundana."

May it be repeated that the war of to-day is biologically revolutionary? In its scope and its nature it is a phenomenon such as has never occurred before in all the history of animal life. A condition without precedent brings an aftermath without precedent.

But, interposes the skeptic, to have effective world organization you must first educate the people and that will take generations. Well, this war undoubtedly is going to be very educative,

on the "speed-up" plan, and widely so with respect to war as an intolerable calamity; but it is no discredit to democratic principles to point out that the control of yellow fever and bubonic plague did not have to wait upon general education and popular demand. Science showed how, and those vested with responsibility and power assumed control, having the sense and courage to adopt vigorous quarantine, eradication and other measures—and the people did not disapprove, although they had not had prior education or even any slight knowledge of the causes and conditions of the disease. For the control of war, as of pestilence, it will be necessary to educate administrative officers and representatives; then, of course, the farther the education of the people can be carried the better.

We have to deal realistically with war and the beginners of war. Whether or not all criminological theorists will agree, I believe it would be the general view that, if murder were rampant in the community, the murderers should be executed or confined. We are now confronted with war and the makers of wars, and the only proper action, whether one likes it or not, is to go just as far in annihilation, or in imposition of "durance vile," as is necessary to create a greater impotence for warfare and a greater distaste for war than some nations have thus far had. You *can* indict a people—*if* you can bomb them, and do not care to do it periodically.

I am optimistic, but certainly not overly assured, as to the development of an organization and a will to permanent world peace. It is conceivable that there will be a peace of adjustment and the initiation of another period of preparation for aggressive war. In such a contingency, we may well be distrustful of the preservation of any respectable social order. My hope for a solution of the crucial problem is based primarily upon the apparent necessity for a solution. Before the present crisis has past, unless I misjudge the prospect, the mother of invention will arise before us, as "a Phantom—with distrustful aspect, Terrible in beauty, age and power," and she will be pregnant with the machinery of enduring peace. We do not know what the baby will look like, but we may have to take and support her whether we had planned for her or not.

THE RURAL SCHOOLS IN WARTIME

Rural America has a tremendous responsibility in wartime. It must supply nearly half of the fighting men. It is providing nearly half of the workers in war industries. It must produce food for victory. It must hold fast to its democratic institutions and to the democratic way of living. In 1940 there were one million more young people under 16 years of age in rural than in urban America.

Only highly trained armed forces can win in modern warfare. Only skilled workers can produce war materials and food for victory. And only a people who have learned to understand and love democracy can defend it. Manpower and materials are necessary but unless we protect our democratic institutions we lose the very ideals for which we are fighting. Education is an integral part of the war effort, and without the public schools we can not have this education. It is significant that Great Britain has increased appropriations for public education each year since the war began. In the dark days ahead, rural America must devote all its natural resources and all its human energies to achieving victory and winning the peace which will follow. But it can not do this if it closes its schools. They are the foundation of democracy in both war and peace. It is essential to winning the war itself and to the preservation of democracy for which we are fighting that schools be kept open and the children provided with the facilities essential to this end.—*C. S. Marsh, in "The Report of a Conference on the Rural Child in the War Emergency."*

A STATE ACADEMY CHARTS ITS COURSE

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THE revival of science in the sixteenth century revolved around such towering university professors as Vesalius and Galileo. However, while the universities seemed to be fit soil for the germination of the new science they were apparently unsuited for its rapid progress. Instead of centers of the new advances in science, they remained "seats of unproductive conservatism, mechanically repeating the formulae inherited from the Middle Ages."[1] During the seventeenth and eighteenth centuries the real pioneer scientists were without university affiliation for the most part. Descartes, Leibniz, Harvey and Leeuwenhoek were all private scholars. These men and others of their kind needed and sought intellectual companionship often found in small friendly groups. Thus it was that scientific societies, or "academies," emerged to furnish the bond between men of learning that the universities did not provide. Patterned upon the Academy instituted by Plato in 387 B.C., these new academies appeared first in Italy but soon spread over Europe and thence to America.

The distinction of being the first such academy of science probably belongs to the Academie Secretorium Naturae, which was founded in Naples in 1560. It was more than a hundred years before the Royal Society of London received its charter in 1662, although a group of kindred minds had been meeting regularly in that city for some time previously. It had existed experimentally and proved its use before being officially recognized. In France, the Académie Royale des Sciences was founded in 1666, and the Prussian Akademie der Wissenschaften in 1700. In this country the American Philosophical Society was first proposed by the many-sided Franklin in a printed circular letter distributed to friends throughout the colonies in 1743.

Franklin envisioned something broader than a merely local club; he had in mind a sort of intercolonial Junto. In his "Proposals" for the society, Franklin stated that now that the first drudgery of settling the colonies was over, there was opportunity for speculation and examination of the natural world. The period of "settling the colonies" was followed by the turbulent times of the Revolutionary War, and it was toward the end of the eighteenth century before other "academies" appeared. The oldest of our state academies of science would seem to be the Maryland Academy, growing as it did out of the old "Academic Society," which was organized in 1797. Of the city academies the records state that the New York Academy dates from 1817.

When we consider the difficulties of communication and transportation, it was natural that city academies should have gotten an earlier start than state academies. The formation of additional city academies of science seems to have definitely ended. None the less, the city academy has had a long and honorable history, and most of them are in a thriving condition to-day. The New York Academy, the St. Louis Academy, the New Orleans Academy, the Washington Academy, the Rochester Academy, the

[1] Eric Nordanskiöld, "The History of Biology," p. 142, New York: Tudor Publishing Company, 1935.

Boston Society of Natural History and others have had a long and successful existence.

Of the state academies, only seven were founded during the nineteenth century and all these, except the Maryland Academy, after the Civil War; three, in fact, during the closing decade of the century. With the opening of the present century the movement spread rapidly. If the present rate of organization is maintained we may expect soon to have an academy of science in each state except possibly certain New England states. These states have lagged in development of academies, for which there are doubtless good reasons which we shall not attempt to list here.

One might well inquire: Whence the momentum for the rapid spread of the academy movement in our own times? Certainly it can not be attributed to the conservatism of our institutions of higher learning. Our colleges and universities are no longer inhospitable to science, although in certain regions and in certain types of institutions the status of science is not all that could be desired. That the original *raison d'être* in some instances has been to provide a bond of fellowship is not to be overlooked, even if only one academy (Virginia) states as one of its objectives "to provide opportunity for . . . fellowship among its members." One contributing factor has undoubtedly been the paternal and fostering attitude of the American Association for the Advancement of Science. The association has helped to organize some academies. It has aided and strengthened the research programs of its affiliated academies. In its academy conference the association furnishes a forum where representatives of the various academies meet on an equal footing for the consideration of mutual problems.

Probably the academy movement stems from the positive desire to make science function in the lives of the citizens of the state by providing a medium through which the state may take advantage of the findings of science, thus helping both the academy and the state to contribute to the general good. This is borne out by the rather striking similarity of objectives of the various academies. For example, it is likely that most would approve the following statement of the Kentucky Academy: "To encourage scientific research, to promote the diffusion of useful scientific knowledge and to unify the scientific interests of the state."

Between objective and accomplishment there is often a great gulf. While this is probably as it should be, objectives are not to be lost sight of altogether. True, many academies can point with justifiable pride to specific attainments of con-

ORGANIZATION AND MEMBERSHIP OF STATE ACADEMIES AFFILIATED WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

	Date of organization	Membership in 1940 or 1941
Amer. Inst. of City of N. Y.	1828	358
Maryland	1797	38
New Orleans	1852	270
St. Louis	1856	415
Kansas	1868	654
Wisconsin	1870	348
Indiana	1885	897
Iowa	1886	681
Ohio	1891	678
Nebraska	1891	184
Michigan	1894	1129
Illinois	1908	1151
Oklahoma	1909	475
Tennessee	1912	459
Kentucky	1914	345
New Hampshire	1919	208
North Carolina	1902	365
Georgia	1922	124
Virginia	1923	912
Northwest	1923	423
South Carolina	1924	281
West Virginia	1924	313
Pennsylvania	1924	445
Louisiana	1927	273
Colorado Wyoming	1927	336
Minnesota	1932*	642
Missouri	1934	720
Florida	1936	346
Alabama	1924	360
British Columbia	1909	104
Mississippi	1931	140
North Dakota	1908	115
Texas	1892†	651

* Reorganized. Data on organization were gathered by Dr. W. H. Schoewe, of the Kansas Academy. Membership data from *Science*, 93: 2414, April 4, 1941. More recent data have been supplied for part of the academies.
† Reorganized, 1928.

siderable merit such as their publications, their summer field stations and their junior academy and science club work. Nevertheless, some academies would have difficulty in justifying their existence in so far as advancing scientific interests and thought within their communities is concerned.

Every one will agree that the aim of a state academy of science should emphasize service to science, not only to its own members but to the science of the state as a whole. While the first function of an academy should be the promotion of research, it is of equal importance to make known its work to the citizens of the state. The academy should likewise act as a clearing house for all the scientific activities of the state. Further, the ideal academy should be on intimate terms with the state's industry and commerce, especially with the greatest business within the state, namely, the state government itself.

Such objectives can not hope of full attainment so long as academies work chiefly upon the basis of one-year plans. Strictly speaking, the annual meeting should recognize such purposes. However, the business meeting is generally swamped by other matters of immediate but not of greater importance. The average academy meets once a year for a day or two, the usual run-o'-mine papers are presented, committees are appointed or continued, the retiring president makes an address and a good time is had by all. Only six academies—Indiana, Oklahoma, Texas, Tennessee, Minnesota and Florida—hold as many as two meetings a year. Contrast this with the situation in city academies: The New York Academy holds twenty-eight meetings, the St. Louis Academy fifteen and the New Orleans Academy five. Interestingly enough, state academy meetings are well attended and membership is on the increase.[2]

In the state academy we have a medium already at hand through which science can flow directly into the lives of our people. The academy can initiate and carry through projects that a national science organization can not undertake. The national organization can coordinate the work of various local groups and can inform one group of what the others are doing. But only the academy can do the job. Men and women are already susceptible to the magic of science, as witness the radio barker invoking the name of science to help him sell his wares. The American people have at their command the benefits and the gadgets of science, but this public remains woefully untouched by science as a way of life. This was made abundantly clear by the venerable A. J. Carlson in his Sigma Xi address in Philadelphia a year ago. Moreover, at no other period in our history have scientists been under such a peculiar obligation to consider science in the broader aspects of its effects upon human beings. Too long has the emphasis of science been upon material things.

I am well aware that it is not customary to report upon an experiment before it has even gotten well under way. But the experiment in socio-scientific planning recently inaugurated by the Virginia Academy of Science is so novel that I venture to describe it in the hope that its very audacity may stimulate other academies to project their thinking into the future along similar lines. Not that the Virginia plan will necessarily fit any other situation, but it should be of assistance to other academies in formulating plans of their own. I am persuaded that even if the Virginia experiment is not carried through to its logical conclusion, the results to date have justi-

[2] From 1936 to 1940 only seven state academies showed a decrease in membership, whereas twenty-two showed increases, and in five cases the change could not be computed. The largest decrease was 16.9 per cent., but nine had increases above this figure. *Science*, 93: 2414, April 4, 1941.

fied its beginning. The members of the academy have a new *esprit de corps* and an awareness of the obligations of science to the people of the state.

Through its twenty years of life the Virginia Academy has followed the pattern of most state academies of science: It boasts a membership of nine hundred; it has fostered research, especially among its younger members; it has organized and is now sponsoring a Junior Academy of Science; and it has a struggling but vigorous *Journal of Science.* If its material success has been more than that of some sister academies, it has been due largely to the good fortune of having had an unusually efficient and devoted secretary during its whole existence.

During the year that Dean Wortley F. Rudd was president-elect of the Virginia Academy he must have given more than the customary amount of thought to academy problems because, when he took office as president in May, 1941, he demonstrated that he knew where he was going. He immediately asked for authorization to appoint a committee on long-range planning for the academy. But before appointing this committee President Rudd consulted each member of the academy with regard to two questions that had been uppermost in his mind during the preceding year. These questions were:

1. What, in your judgment, should be the primary objectives of a state academy of science?
2. Please outline rather carefully, and in order of their importance, three or more distinct contributions that the academy may and should make to Virginia in the next five years.

The same two questions were sent to the members of the National Association of Science Writers, to the secretaries of all state academies and to a large group of distinguished scientists throughout the country. Returns from all these sources were excellent and the replies often make interesting reading. From the membership there were one hundred and fifty-two letters of response containing four hundred and fifty-seven suggestions. All these data were abstracted and the suggestions classified[3] under the following headings: Research; Publicity of Academy's Work; Science Education; Problems concerning the State; Science Clubs and Junior Academy; Guidance Program; Academy Meetings; Providing Science Materials; Water Pollution; National Defense; Science Museum; Problems concerning Industry; Retaining Virginia's Trained Scientists, and Miscellaneous. Since the items are here arranged in the order of their frequency, one can see that our scientists still conceive of the promotion of research as the primary function of a state academy of science. Research was mentioned in 71 per cent. of the replies, Publicity of the Academy's Work in 46 per cent., Teaching and Science Education in 44 per cent., and Problems concerning the State in 28 per cent.

The selection of the personnel of the Long Range Planning Committee was carefully arranged as follows: About twenty of the "most experienced and devoted members" were asked to nominate five or six persons who would meet the requirements for membership on such a committee. Nominations were not confined to academy members. From the resulting eligible list of around one hundred names, the final selection of nearly twenty-five was made by a small group around the president. Interestingly enough, not one person declined to serve.

Armed with the information from the questionnaire, President Rudd convened the Long Range Planning Committee on October 25, 1940. The response was in-

[3] By Mr. H. J. Davis, of Williamsburg, Va., through whose efforts the Virginia Junior Academy of Science was organized. Summaries of his report on data are available. Write Dr. E. C. L. Miller, Secretary-treasurer of the Academy, Medical College of Virginia, Richmond.

deed gratifying—only six members were absent, and each absentee sent in a satisfactory explanation of his absence. The president of one of the state's institutions of higher learning traveled two hundred miles to attend. The organization of the committee was soon completed. The unanimous choice for chairman was Mr. L. C. Bird, who had shown his ability as general chairman of the Richmond meeting of the American Association for the Advancement of Science in 1938. Dr. Sidney S. Negus, assistant secretary of the academy, was made secretary of the committee as well as of its executive committee. At its first meeting the executive committee set up a number of committees that would encompass most of the suggestions received from the questionnaire.[4]

It was agreed that the academy should capitalize upon the manifest interest of its membership. Obviously, although the half-dozen committees were designed to include most of the topics upon which action was demanded, some topics were almost certain to be sidestepped. Therefore the question put to the scientists and professional leaders who made up the Long Range Committee was: How could such a wide diversification of ideas be unified into one major objective, an objective that would appeal to the entire academy membership and at the same time capture the imagination of the citizens of the state? It was obvious from the nature of the topics suggested that only a project of wide range could elicit the whole-hearted interest of such a group of scientists. Further, if the aims of the academy were to be achieved, the project must have a name with which every one is already familiar, a name that is of significance in the scientific, economic, social and even the romantic life of the state.

[4] A few copies of the minutes of this first meeting as well as those of the executive committee are obtainable from Dr. E. C. L. Miller, secretary-treasurer of the academy.

As every writer knows, finding the right name is sometimes as difficult as writing an article. In our case that name was soon forthcoming[5]—The James River Project, it should be. Careful inspection of the map of Virginia will show that from its westernmost boundary to Chesapeake Bay, the James River transects all the physiographic provinces of the state—the Allegheny Ridges, the Great Valley, the Blue Ridge, the Piedmont and the Coastal Plain. Of the one hundred counties in Virginia, forty-two are either wholly or partially within the James River drainage basin. Most of the other counties have close association with those forty-two. The majority of the educational and research institutions of the state are located within the forty-two counties of the James River Basin. For generations the mighty James was the principal artery of travel of the state; it is renowned in song and story—the Old Man River of a state. The river is as characteristically Virginian as tobacco or peanuts. In this great river we have our unifying idea around which to correlate scientific, sociological and historical research. The project is enormous, being nothing less than the planned study of a large region as a human habitat.

The approach to the problem is essentially twofold. First, there is to be a survey and compilation of what is already known about existing conditions within the area. Secondly, there will be the extension of our knowledge of the region together with the scientific improvement of existing conditions.[6] The first phase of the project, which is to be

[5] At the suggestion of Mr. Justus H. Cline, of Stuarts Draft, Virginia, and a member of the Long Range Planning Committee.

[6] Much of the material that follows is taken, sometimes almost verbatim, from a preliminary statement prepared by Dr. Marcellus H. Stow, who is chairman of the James River Project. A few copies of this statement are available and may be procured by writing Dr. Stow at Washington and Lee University, Lexington, Virginia.

completed during the present year, will attempt to answer such questions as: What is the *present* land-use? What is the *present* status of conservation of mineral resources, of wild life, of forests? What are the *present* conditions of education, of public health, of agriculture, of industry? The second phase, which is to be directed toward the scientific improvement of present conditions, is definitely not a reform movement. The academy will not attempt to put trout in all the mountain streams, but by a scientific study will attempt to determine the conditions under which trout thrive. Instead of a campaign denouncing stream pollution, the academy would undertake a scientific study to determine exactly what constitutes pollution and the means whereby pollution can be avoided, to the mutual benefit of all interests. It is proposed to keep the work on a high plane of scientific research, not becoming involved in the vagaries of politics nor a crusade against "vested interests."

May I again recall that the preliminary survey of the opinion of the academy members revealed the fact that informing the public of the activities of the academy was mentioned more often than any other item except research. This in spite of the inclination of scientists to pursue the even tenure of their way without much regard for what the people think about them or their work. "Research workers are therefore running the risk of becoming isolated from the general mass of the population in our social order," declares Austin H. Clark; and, further, "The history of science—and the varying status of scientific research in the different countries of the world to-day, show us that scientific advance, at least in certain lines, is conditioned by the attitude toward it on the part of the general mass of the population as reflected by their chosen representatives."[7]

[7] Austin H. Clark, THE SCIENTIFIC MONTHLY, 52: 257–260, March, 1941.

In science we will continue to get new facts, new techniques, new principles— these things we can take for granted. What we can not take for granted is the attitude of the people toward the results of science. If science is to prosper the population as a whole must take an interest in and appreciate the work done by scientists. The people can not be asked and will not cooperate just as a favor to scientists but must see in scientific work something of essential value to themselves. The Virginia Academy of Science is determined to take the people of Virginia into its confidence. This is partly the reason why the first major phase of the present experiment will be the publication of a Monograph to be entitled "The James River—Past, Present, Future." This is not being done primarily because it is good policy but because it is the right thing to do.

This monograph, which will be a quarto volume of around six hundred pages, is expected to be published within the year. It will obviously be incomplete, but it should direct attention to the needed fields of investigation and thereby serve as a stimulus for a state-wide undertaking to which scientists and others can contribute. In addition, it should acquaint the non-scientists of the state with the work of their state academy.

In the words of Dr. Stow:

> We wish to present a brief history of the development of these sciences in Virginia, to discuss the contribution that each has made toward the improvement of the region as a Human Habitat, to present and to indicate problems that await initial study or more detailed scrutiny in order to improve the region scientifically, industrially and sociologically. If we may borrow a phrase from the biologists, we wish to make a study of Human Ecology—man's environment—and to ascertain methods of improving it.

Scientists may well inquire as to the reaction of the public to the project. It is still too early to gauge accurately such reaction, but thus far the results have been gratifying. Non-scientists are serv-

ing on the various committees. We have been fortunate in receiving the cooperation of men prominent in science and industry in the compilation of information for the Monograph. "We believe such a monograph, written by competent authorities, will do much toward developing and improving the status of science, industry, and social conditions in the James River Region, and hence in Virginia."

"Essentially there are two types of scientists—one is the fundamental research man who is interested in learning only what happens or what results from a given set of conditions; the other is one who is interested in the application of these fundamentals to the development of processes, methods of manufacture, or creation of new commodities." Both types are essential, but all too frequently the fields of the two are not brought together. It is hoped that the James River Project will do much toward remedying this situation.[8]

Recently in London, England, there was held a very significant conference on "Science and World Order." Much was said at that conference about planning for the future but, as one speaker remarked, planning can never be more than an "administrative convenience" until it is brought into direct contact with human needs. Science may have to reverse certain of its past attitudes. No longer can scientists regard themselves as "mere consultants sitting in remote laboratories," but as active participants in the world of affairs. The human value of science lies in the moral quality of the human purpose directing it. In the words of Edwin Markham:

> We are blind until we see
> That in the human plan,
> Nothing is worth the making, if
> It does not make the man.
>
> Why build these cities glorious
> If man unbuilded goes?
> In vain we build the world unless
> The builder also grows.

[8] Indicative of this new spirit between science and industry it might be mentioned that the Virginia Manufacturers Association invited the Virginia Academy of Science to participate in its annual meeting last October. The academy presented a symposium on the subject, "The Value of Scientific Research to Virginia Industry." Participating in this symposium were: Dr. W. S. Calcott, director, Jackson Laboratory, E. I. du Pont de Nemours and Company; the late Dr. Harrison E. Howe, Editor, *Industrial and Engineering Chemistry,* and Dr. Arthur Bevan, Virginia State Geologist.

SOCIAL CONTINUITIES IN CYPRUS

By Dr. JOHN FRANKLIN DANIEL

THE UNIVERSITY MUSEUM, UNIVERSITY OF PENNSYLVANIA

THE archeologist is often faced with the problem of relating the objects and conditions he discovers on an ancient site with similar manifestations of present-day life. In many regions this involves little more than a feet-on-the-ground attitude, but in a land such as Greece or Cyprus, where there is an unbroken cultural tradition from antiquity to the present day, the problem becomes much more important.

Much has been written, most of it polemic in nature, about the degree of connection between ancient and modern in Greece and the Greek outposts. While scholars are gradually coming to an agreement, the general public has suffered from the vociferous protestations of certain starry-eyed classicists who feel uncomfortable in modern Greece because its inhabitants are human, and resent the fact that there are not glaring white marble statues of the gods on the most striking hill-tops. Adherents of this school argue that the Greek blood has been hopelessly dispersed by repeated invasions of Goths, Slavs, Franks and Turks; that these invasions have reduced the Greek language to a hodge-podge which refuses to follow reasonable linguistic rules; that all intellectual vitality and integrity is gone; and that even the supposed survivals of Greek religion are merely part of a confusing and disgraceful body of superstition.

Fortunately this school has been publicly discredited by the heroic stand of the Greeks in the face of the latest and worst of vandal incursions. The public is now willing to believe, and the best scholars know, that whatever may have happened to Greek blood, Greek character and intellect have lost nothing, and that even the spoken language is no further from that of Plato than Plato himself was from Homer.

The course of events during the last decade finds parallels in the most glorious pages of Greek history. In this war, as so often in the past, the Greeks were torn asunder until almost the last hour by political feuds, in which all took part, and all appeared to be inviting disaster. When, however, disaster appeared, a moratorium was declared on personal animosities, and the entire populace united, even behind a hated dictator, to destroy the common enemy.

The temperamental similarity of the modern Greek to his famed ancestors was evident even before the war. The schoolboy whom I once met on the train, who was going to Athens to complain to the Prime Minister about his village school and who undoubtedly saw him and argued heatedly, was in the best classical tradition. The humor, compounded of ribaldry and politics, of a modern Athenian musical comedy is amazingly like that of Aristophanes.

General observations of character are of use to the field archeologist in more ways than one, but by and large he is concerned with a different aspect of the continuity from antiquity. In many cases he will find it difficult to determine whether an obvious similarity indicates a real generic connection or whether it is merely a coincidence.

While excavating in Cyprus among the remains of a city which was inhabited from 1600 till about 1000 B.C., I was frequently struck by resemblances in detail between the ancient city and the nearby

modern village of Episkopi. The general type of construction of at least the simpler houses of the ancient city was remarkably close to that of the village houses of the present day. In both, the walls averaged about eighteen inches in thickness, and both were built of a superstructure of sun-dried brick laid on a foundation of rough stones a foot or two high. The similarity went even to minor details. The bricks were about eighteen inches square and five or six inches thick in both periods, and both were made with a chaff temper. The ancient bricks often contain small potsherds and other ancient objects, proof that they were made of earth dug within the confines of the city rather than at a suitable clay bed in the country. At the present time in Cyprus some brick is made at factories, but most of it is still produced locally in the villages. The village brick-makers do not have permanent workshops, but move around from one spot to another, making the bricks for each job separately, and as near to the projected house as possible. There is every reason to believe that this practice is the same as in antiquity.

In excavating one house of the twelfth century B.C., I was puzzled by large patches of white clay, pure, save for some carbonized vegetable matter, which lay directly over the ancient floor. The workmen called my attention to the fact that this same white clay is used to-day in waterproofing earth roofs, and even pointed out the only bed in the neighborhood where the material is obtained. Roofs in the modern village are almost flat but have a slight slope to one side to carry off rain water. They consist of beams laid longitudinally across the room, over which is placed a layer of reeds or matting. This is then covered with six to ten inches of ordinary clay, and finally dressed with a thinner layer of the white clay. In view of the other similarities, it seems not unreasonable to suppose that the roofs of the ancient houses were much like those described. The only difference is that the ancient roofs seem to have dispensed with the layer of ordinary clay; the white clay was apparently placed directly over the reeds or mats.

The ancients kept their water, olive oil, wine, grain and many other foods in large storage jars. These jars might be placed on the floor in the corner of the room, or else sunk below the floor with only the rim showing. Another system of storage, used primarily for grain, was to dig a deep hole in the ground, line it with clay, and then light a fire in it which baked the clay, thus keeping the pit clean, rat-proof and relatively dry. Storage jars, similar in both shape and use to those of the early city, are found in almost every village house in Cyprus, and underground clay-lined storage pits are still found in at least one town on the island.

More examples might be mentioned, but these serve to illustrate the marked similarity in conditions in antiquity and now. Any one of these might be a coincidence, for given like needs and like resources, similar results are probable. In this case, however, the large number of similarities argues against coincidence. We know that this region was occupied without any radical break from very early times right down to the present day. There were several migrations from abroad and several foreign conquests, but there is nothing to indicate a complete change of population in connection with any of these. The worst disaster which ever befell the city was the earthquake in the fourth century A.D., as a result of which the classical city was abandoned, and the inhabitants moved to the site of the present village. But even this did not fundamentally affect the race and customs of the inhabitants. There is therefore every reason to believe in a direct continuity in the

ethnic and cultural traditions of the village.

If we are correct in assuming that there is such a continuity, modern village life assumes a new importance for the excavator, who may hope to find explanations of some of his archeological mysteries in the conditions of the present day. This does not mean that one can assume complete identity, or overlook the possibility of gradual, but nonetheless profound changes. For example, in spite of the similarity in architecture and in household appointments, Episkopi is a relatively humble agricultural village, whereas we know that its predecessor was a large and prosperous city and for centuries the capital of a kingdom. Among the ancient ruins we have found objects in gold and ivory such as the modern inhabitants of Episkopi have never hoped to own. When, however, we find in the excavations enigmatic objects of some humble material not mentioned in the text-books, but identical with household objects in use in the village to-day, we are perhaps justified in assuming that the ancient object served the same use as its modern counterpart.

Perhaps more important, and certainly more difficult to trace, than a continuous tradition in the use of certain artefacts, is a survival of certain prejudices and attitudes. One of the minor puzzles of Cypriote archeology is the fact that Cyprus continued to produce pottery laboriously by hand centuries after its neighbors had adopted the use of the potter's wheel. It was long thought that this illustrated a Cypriote resistance to new ideas. We now know, however, that Cyprus did know the potter's wheel by at least 1600 B.C. and used it for certain types of wares while it continued to produce others by hand. It is not until fairly recently that scholars have come to realize that there is an excellent parallel to this in the island to-day, for the most popular type of water jar in Cyprus is still made by hand. Another peculiarity of Cypriote ceramics was the predominance of round bottoms on their vases. Though ring bases were known from a fairly early date, the stability which these offered was not particularly cherished, and the round base reigned supreme for centuries. Most of the water jars, both hand- and wheel-made, in use in the island to-day have round bases. The wheel-made jars are almost identical in shape and fabric with jars used there in the classical period; the hand-made jars practically duplicate a favorite type of the third millennium B.C., with a hand-burnished red slip and incised decoration. The shape is also closely paralleled in the early period. It would be logical to assume that the modern jars are imitations of ancient vases seen in the museum or elsewhere. This is, however, by no means certain, for the modern tradition appears to go beyond the time when archeology might have furnished prototypes.

The fondness for the round bottom may have its basis in the native psychology. In the steaming Cypriote summer a thirsty man wants his drink in a hurry, and a round-bottomed jar is more easily tipped. After being refreshed he is perfectly willing to spend ten minutes rebalancing the jar, particularly so if he is a workman being paid by the hour.

This article has not posed new problems or furnished important new evidence in favor of a view which is in the course of being accepted by scholars. It does, however, try to stress the integral relation between present conditions and those of the more or less remote past. Thus not only the archeologist should make a careful study of modern village life as an aid in his own study of antiquity, but the classicist who is inclined to deprecate the present inhabitants of historic lands, should not forget that even their heroic ancestors were human.

BOOKS ON SCIENCE FOR LAYMEN

DEVELOPMENT OF THE VERTEBRATES[1]

IN this handsome large-octavo volume the University of Chicago Press has added another masterpiece to its science series. In a little over four hundred pages of text and in a remarkably simple and understandable way the author has told the epic story of the rise and branching out of the vertebrates from even before *Amphioxus* to man. The hundreds of illustrations represent the best of their kind in line and half-tone. This work is distinctly not "a little of everything," but a thoroughly integrated mosaic. In the reviewer's experience no other single work has succeeded so brilliantly both in telling the grand story of vertebrate evolution and in holding the mirror of science up for man to see himself as part of that story.

No single human brain could be equally familiar at first hand with the vast fields of paleontology, systematic zoology, embryology, physiology, anthropology, archeology, etc., which have contributed of their best to this work, and the author acknowledges the constant assistance of his former colleagues at the University of Chicago who contributed from the material used in their courses; nor does he neglect the American Museum of Natural History, the New York Zoological Society and many other sources whose treasures of illustrations were freely opened for this work. Joyful cooperation and close checking of the text by the author's wife and others have eliminated errors to such an extent that the reviewer succeeded in noting only one: *i.e.*, the provisional reconstruction of *Plesianthropus*, opposite page 183, is by Gregory and Hellman, from Broom's specimens.

The chapter on the frog is a welcome relief from the dry-as-dust method of the ordinary laboratory manual, partly because it treats anatomy and physiology together. As its topics are arranged in the same order as those in the chapter on human anatomy, the student is advised to compare the two organisms, contrasting their diverse specialization for locomotion and noting the many other ways in which the frog is more primitive than man.

The chapters on human anatomy and anthropology, which take up nearly half the book and in which the influence of Professor Griffiths Taylor is gratefully acknowledged, would form an admirable volume even by themselves but gain greatly by being connected with the general story and with the sections on the mammals, on the origin of the mammals and by the contrast in the basic physiology and anatomy of the various classes.

This book must long retain its leadership for general reading, for careful study and for perspective in diverse branches of biology.

WILLIAM K. GREGORY

[1] *Man and the Vertebrates.* Alfred Sherwood Romer. 3rd edition. Illustrated. viii + 405 pp. $4.75. November, 1941. University of Chicago Press.

THE STORY OF MODERN CHEMISTRY[1]

THE chemical world has long needed a successor to E. E. Slosson's "Creative Chemistry," the phenomenal success of 1918, now out of print. This is it—as interesting a book on the development and present status of the synthetic organic chemical industry as any one can hope to see. Its swift conversational style is almost gossipy in its light touch and in its facile portraiture of scores of

[1] *This Chemical Age.* Williams Haynes. Illustrated. xxxiii + 385 pp. $3.50. 1942. Alfred A. Knopf.

chemical personalities of the nineteenth century and of the present. Yet, quite unobtrusively it is packed with facts and figures on this great industry that are authoritative and precious even to chemists.

It is written from the inside, for Williams Haynes was for years editor of *Chemical Industries*, knows everybody in "the game" and has himself played a prominent part in the meteoric rise of the industry since 1914. But it is written from the inside out, as every good book should be, for the author knows the public as well as he does his colleagues, has a journalist's sense of what the reader does not know and wants to. The result is a book for business men who deal with chemical materials, for economists, lawmakers, and above all for the young man about to choose a career.

There are twenty chapters, all in high gear, a brief bibliography (which is characteristically entitled "If You Want More"), an excellent glossary and a complete, 22-page index. The subjects covered are: dyes, perfumes, "sulfa-" drugs, camphor, rubber, petroleum products, cellulose, rayon, nylon, plastics and a final chapter on war chemicals, including toluol, explosives, nitrates, potash, incendiaries, all as of just before Pearl Harbor. It will in a few years be a precious record of just what we started with on that day. The sub-title, "The Miracle of Man-Made Materials," is correct, except that the full and candid treatment of each subject replaces the apparent miracle in each case by good solid science. The title itself, I regret to protest, is too sweeping, for there is much more in this chemical age than organic synthesis. Even Slosson's less ambitious title included fertilizers, corn products, chemical warfare, the electric furnace, metallurgy, radioactivity, nutrition, vegetable oils and fats. To justify the title would have required a far larger book.

Most commendable is the fact that the "miracles" of industry are not presented as spectacular magic but as the logical outgrowth of many years of painstaking research. The book actually begins with Henry Cavendish and the composition of water. The discussion of dyes begins not with Perkin but with the story of Liebig, way back in 1845, who recommended A. W. Hofmann for a professorship at the Royal College of Chemistry, and who in turn had a student named Tommy Hall, who as instructor at the City of London School later discovered the precocious lad, Perkin. Then the detailed story of the work of 18-year-old Perkin in Hofmann's own laboratory and his tongue-lashing by Hofmann when he left the college for the commercial development of mauve. Step by step the slow fifty-year growth of the industry from that day on to Germany's well-earned dominance is told. A wealth of detail not previously published in book form its evidence of enormous historical research. Supplemented by the author's intimate personal knowledge of the events since 1914, this becomes a valuable source book for chemists and a fascinating biography of the childhood and youth of one of the most powerful factors in our present civilization. One can not but hope that Williams Haynes will be spared to write the history of the maturity of his beloved industry during the next twenty years.

GERALD WENDT

PSYCHOLOGY AND THE PRACTICE OF MEDICINE[1]

IN the past generation the science of medicine and the resulting rise of specialization have sometimes obscured to the physician and surgeon the fact that the patient is a person instead of a mere aggregation of parts. Yet the successful doctor, whether he admits it or not,

[1] *Psychotherapy in Medical Practice.* Maurice Levine. xiv + 320 pp. $3.50. 1942. The Macmillan Company.

is a psychiatrist in the sense that he deals with the patient's personality as well as with his affected organs. Indeed, often the organ complaint may be merely the manifestation of a psychological problem!

Dr. Levine, an experienced and thoroughly trained psychiatrist, presents here a clearly, simply written but comprehensive account of how the general medical man may avail himself for the benefit of his patient of the simple truths of psychiatry. Defining psychotherapy as therapy by psychologic measures, he continues: "By psychologic measures we mean that the treatment is done through the patient as a whole, not through some of the parts of his body. It means that the treatment works through the functions that are associated with his highest integrations, through his speech, his perceptions, his thinking, his emotions, and his relationships with other people and other objects. It means treatment applied directly to the 'mind,' by which we mean not a separate entity, but the functioning of the person as a human being.

"Psychotherapy includes the direct treatment of one person, as a person, by another. It includes also the indirect treatment of one person by another, through the intermediary of other persons or situations. A rearrangement of the patient's family life by the physician is psychotherapy, just as a direct discussion of problems with the patient, is psychotherapy." Beginning with a chapter on Common Misconceptions (such as that heredity is the chief cause of psychiatric disorders, that there is a sharp difference between "normal" and "abnormal," that psychiatric illness is a disgrace, that marriage cures all varieties of psychiatric disorders, that the ideal child is always obedient, for example), he discusses the general Methods of Psychotherapy, Methods for the General Practitioner, Methods for the Specialist, Suicide Risks, The Study of Psychogenic Factors, The Choice of Cases, Sex and Marriage, Basic Attitudes toward Children, The Problems of Parents and Children, and Normality and Maturity.

The volume is so packed with sound advice that it can not well be abstracted; perhaps the reader of this review would not especially care for an abstract. Although the book is designed primarily for medical practitioners, it can be read with profit by the intelligent layman who is interested in psychological medicine. Certainly every physician in practice will profit by a careful perusal of this very useful addition to medical literature.

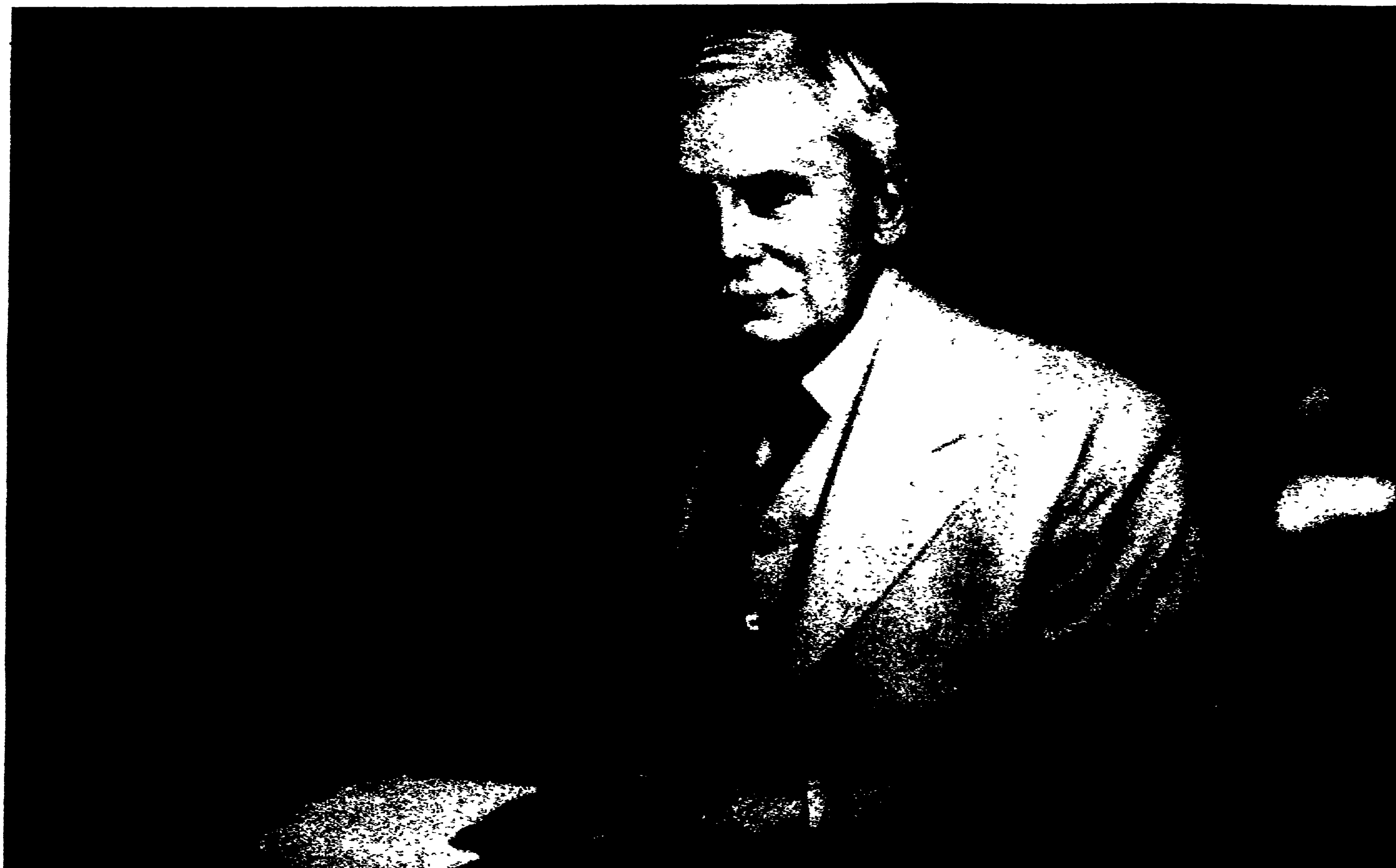
WINFRED OVERHOLSER

A STUDY OF MUSIC[1]

HERE is a comprehensive textbook for students of music, covering musicology, defined by the author as "that branch of learning which concerns the discovery and systematization of knowledge concerning music." It is well documented but has no illustrations. The topics are well chosen, but as a text the book will not go far except in the hands of the teacher who is familiar with sources of the materials. The general reader who is not a specialist in some field of musicology will see in this book a skeletal outline as sketched by a practical musician.

CARL E. SEASHORE

[1] *Introduction to Musicology.* Glen Haydon. viii + 329 pp. $4.00 1941. Prentice-Hall, Inc.



CHARLES SCHUCHERT, 1858–1942

THE PROGRESS OF SCIENCE

CHARLES SCHUCHERT, 1858–1942

PROFESSOR CHARLES SCHUCHERT, distinguished paleontologist and stratigrapher and foremost authority on paleogeography, died on November 20, 1942, in New Haven, Connecticut, in his eighty-fifth year. At the time of his death he was seeing through the press the second volume of his great synthesis of North American stratigraphy, due to appear on December 15 of this year, and had nearly finished writing the third and final volume with all the eager keenness and enthusiasm that were so inspiring to those privileged to know him. The photograph of Professor Schuchert here shown, taken at the age of eighty-two, portrays remarkably well the man as we knew him, deeply respected and greatly beloved colleague.

Born in Cincinnati, Ohio, on July 3, 1858, he was destined by the circumstance of his environment to make paleontology his future career. At the age of eight his interest was aroused by a fossil coral casually given to him. This started him collecting the fossils so wonderfully well preserved in the strata exposed in the hills of Cincinnati. His parents did not encourage him to go into paleontology as a profession; in fact, his father often told him that if he paid as much attention to the furniture business as he did to the gathering of fossils he would some day be a rich man. However, as Schuchert long afterwards confessed, making furniture was hard work, but collecting fossils and learning their meaning was "endless pleasure." His father died while the boy was still young, and the future paleontologist on receiving his patrimony of $1,400 spent half of it in enlarging his collection of fossils.

From 1885 to 1888 Schuchert was assistant to Edward O. Ulrich, curator in charge of the Cincinnati Society of Natural History, who was then just beginning the career that made him also one of the foremost paleontologists of his time. From Cincinnati Schuchert went to Albany, New York, to become the personal assistant of the great master of paleontology, James Hall, of the Geological Survey of New York. Hall, whose appetite for acquiring collections of fine fossils was well-nigh insatiable, made the appointment contingent upon Schuchert bringing with him his brachiopods and letting "us have the use of them and his knowledge of them." The new assistant soon proved highly useful because of his great ability and enormous capacity for work. During his stay at Albany he became intimately associated with the brilliant young paleontologist, John M. Clarke.

From Albany Schuchert went to Minneapolis, where he served a short time on the Geological Survey of Minnesota, mainly in preparing a volume on the Brachiopoda. He then became preparator of fossils for Dr. Charles E. Beecher at Yale University. In 1893 he was appointed assistant paleontologist on the U. S. Geological Survey and in 1894 he became assistant curator at the U. S. National Museum, where he remained until 1904. In that year he accepted a call to Yale as professor of paleontology and curator of the geological collections of Peabody Museum and as professor of historical geology in the Sheffield Scientific School, to fill the positions left vacant by the death of Charles E. Beecher. Here he had to make, as he himself has characterized it, "the somewhat painful metamorphosis from curator to professor." The metamorphosis, though it may have been painful, was eminently successful, and he became acting dean of the Graduate School, 1914 to 1916, and chairman of the department of geology from 1919 to 1921.

On reaching the age of sixty-five in 1923, Professor Schuchert decided that in view of the large amount of research work he had in hand he would retire from his teaching and administrative duties. Rich in experience, equipped with an encyclopedic store of information on his chosen fields, and open to all new ideas, Professor Schuchert produced during the two decades after his retirement a great body of work that few younger men can hope to accomplish in the same span of time. It has been a real surprise to many that Professor Schuchert should have accomplished so much in his chosen science and attained such preeminence without the benefit of a college or university training. Perhaps, as has been suggested in somewhat lighter vein, he did not have to learn and unlearn the theories of professors. But, as David White has said, "where could a student have found more satisfying courses in Paleozoic paleontology than under Ulrich, Hall and Clarke, Beecher, and Walcott?"

Professor Schuchert has made outstanding contributions in many branches of geology. In his early years his interests were almost wholly centered in invertebrate paleontology and Paleozoic stratigraphy. His devotion to these subjects never waned, but as time went on his interests broadened more and more to the philosophical aspects of his science. The phylogeny of the Brachiopoda, the climates of the geologic past, the delimitation of the geologic systems, the dating of mountain-making movements and the doctrine of geosynclines are some of these. Transcending all these, however, were his paleogeographic studies and the resulting paleogeographic maps, on which are shown the distribution of land and sea in the geologic past. In 1910 he published his now classic "Paleogeography of North America," in which were shown the distribution of the seas at fifty successive stages in the history of the North American continent. These maps were a notable advance on all earlier attempts, in that far narrower time limits were used than had previously been employed; that is, the boundaries of the seas were shown as they were conceived to have existed at a definite instant (geologically speaking) in the history of North America. Moreover, the correlations were more precise than those previously used. Later the maps were republished in revised and improved form. They now number nearly 125. To the end of his life, Professor Schuchert kept these maps up-to-date by including all new information as it came in. Paleogeographic maps of other continents were drawn. These paleogeographic studies attracted world-wide attention and brought their author international fame. A wholly unexpected outcome of the paleogeographic maps, gratifying to their author, was their wide use by petroleum geologists in the search for oil.

Many honors have come to Professor Schuchert. He was elected to the National Academy of Sciences in 1911. He was president of the Paleontological Society in 1910 and president of the Geological Society of America in 1922. The degree of LL.D. was conferred on him by New York University in 1911, the doctorate of science by Yale University in 1930 and the doctorate of science by Harvard University in 1935. The Hayden Gold Medal was awarded to him by the Philadelphia Academy of Natural Sciences in 1929; the Mary Clark Thompson Gold Medal by the National Academy of Sciences in 1934; and in the same year the Penrose Medal of the Geological Society of America, which is conferred "in recognition of eminent research in pure geology" and "of outstanding original contributions or achievements which mark a decided advance in the science of geology." His eminence was also recognized by election to honorary membership in scientific societies in Great Britain, Germany, Austria, Russia, Belgium, Sweden and Norway.

ADOLPH KNOPF

POSTPONEMENT OF THE NEW YORK MEETING OF THE AMERICAN ASSOCIATION

A GREAT meeting of the association was scheduled to be held in New York City during the week beginning on December 28, 1942. Forty-four affiliated societies were expecting to meet with the association. Plans for more than two hundred separate sessions had been nearly completed and nearly two thousand papers were being written. The program was printed and exhibits were being assembled. Then, on a request from the Office of Defense Transportation, the meeting was postponed. It was not postponed to a definite date, because none could be determined with the future depending on the course of the war and its effects upon railway transportation in this country.

Naturally there were disappointments at the sudden change of plans. But scientists realize that greater things than the holding of a scientific meeting are now at stake in the world. The future of science, indeed of freedom, is in the balance. Under these circumstances scientists were willing to forego the pleasures and advantages of attending the meeting and turned their energies to the urgent matters of the day.

Among the general addresses scheduled for delivery at the New York meeting was the retiring address of Dr. Irving Langmuir, who was president of the association during 1941. The subject he had chosen for his address was "Science, Common Sense and Decency," a title which could not fail to arouse the curiosity of all who read it. A second general session was to be that at which the annual Sigma Xi address was scheduled to be delivered by Dean John T. Tate, of the University of Minnesota. The annual Phi Beta Kappa address was to be delivered by the Honorable Dr. Hu Shih,

DR. A. J. DEMPSTER
PROFESSOR OF PHYSICS, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON PHYSICS.

DR. JOHN T. BUCHHOLZ
PROFESSOR OF BOTANY, UNIVERSITY OF ILLINOIS; CHAIRMAN, SECTION ON BOTANICAL SCIENCES.

DR. CHESTER R. LONGWELL
PROFESSOR OF GEOLOGY, YALE UNIVERSITY; CHAIRMAN OF THE SECTION ON GEOLOGY AND GEOGRAPHY.

formerly Ambassador from the Chinese Government to the Government of the United States.

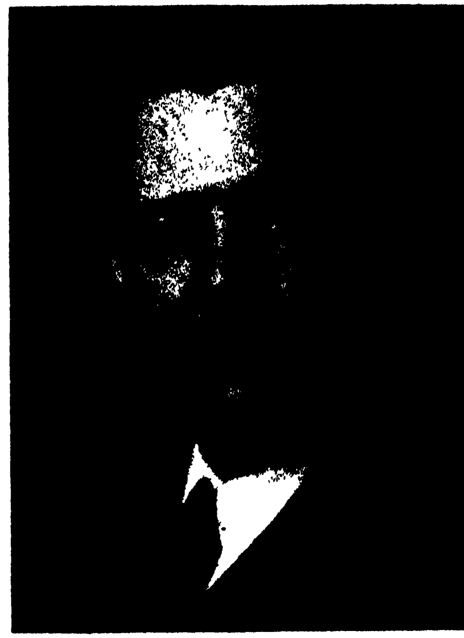
Finally, addresses were to be delivered by the retiring vice-presidents of the association; there is a vice-president for each of the fifteen sections under which its work is organized and of which they are the respective chairmen. Their addresses, too, were postponed, but it is hoped that arrangements will be made for their publication even though they can not be delivered as planned. The vice-presidents are among the most eminent scientists in their respective fields and their addresses are correspondingly worthy of attention. The presidents of most of the affiliated societies intending to meet with the association were also scheduled to deliver their retiring addresses, but their voices were stilled by the postponement of the meeting and they must deliver them at some local meeting or resort to publication without oral presentation.

DR. HUGH S. TAYLOR
DAVID B. JONES PROFESSOR OF PHYSICAL CHEMISTRY, PRINCETON UNIVERSITY; CHAIRMAN OF THE SECTION ON CHEMISTRY.

DR. W. C. ALLEE
PROFESSOR OF BIOLOGY, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON THE ZOOLOGICAL SCIENCES.

With so many casualties due to an action that came as suddenly as the attack on Pearl Harbor, it might be supposed that the association and its affiliated societies are in a state of considerable confusion. However, such is not the case. Scientists should have, and do have, stabilities acquired from their studies of the world of nature about them. They do not doubt that present storms will pass away and that spring will come again. They are sure, similarly, that the cold hatreds now hardening the hearts of men will eventually melt into the human kindness that has existed in every age and among every people. They look forward with confidence to the time when they can work again directly for the welfare of all their fellow men.

Although the view of distant goals that science gives maintains the courage, the tasks at hand must be carried out under existing conditions, and they are far different from those for which scientists long. The demands of war have



DR. HAROLD HOTELLING
PROFESSOR OF ECONOMICS, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON THE SOCIAL AND ECONOMIC SCIENCES.

DR. HENRY E. GARRETT
ASSOCIATE PROFESSOR OF PSYCHOLOGY, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON PSYCHOLOGY.

DR. MORRIS R. COHEN
PROFESSOR OF PHILOSOPHY, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON HISTORICAL AND PHILOLOGICAL SCIENCES.

compelled scientists in every field, for example, the vice-presidents of the association whose portraits are reproduced on these pages, to lay aside the investigations on which they have been engaged to take up others of immediate and urgent importance. Laboratories have lost largely of their staffs and been greatly depleted of their equipment. The routines of the lives of individuals have been interrupted, hours for rest have been greatly reduced, recreation and relaxation are disappearing, normal home life has been broken, the leisure for reflection that has always been deemed essential no longer exists—yet, with very few exceptions, scientists have risen to new heights of productivity under these supposedly adverse conditions without suffering any serious ill effects. Perhaps many of the luxuries of life are more harmful than beneficial, because the human organism and the human mind have not yet learned how to use them advantageously, or perhaps have not yet acquired a tolerance for them. If this is true, science in the near future should set new goals for attainment, goals that on the physical level include higher ideals of perfection, goals that on the intellectual level include broader acquaintance with nature and man, and goals that on the moral level make the apparent interests of the individual inferior to the interests of the whole. Perhaps it requires the shocks of war to teach what should be obvious, both from human history and through reason.

In spite of present disruptions, scientists have no fears that the importance of science will decline in the world. On the contrary, they confidently expect that after the close of the war it will have its greatest period of activity, and that then it will render its greatest service to mankind because careful attention will be

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DR. A. E. MURNEEK
PROFESSOR OF HORTICULTURE, UNIVERSITY OF MISSOURI; CHAIRMAN OF THE SECTION ON AGRICULTURE.

DR. HAROLD F. CLARK
PROFESSOR OF EDUCATION, TEACHERS COLLEGE, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON EDUCATION.

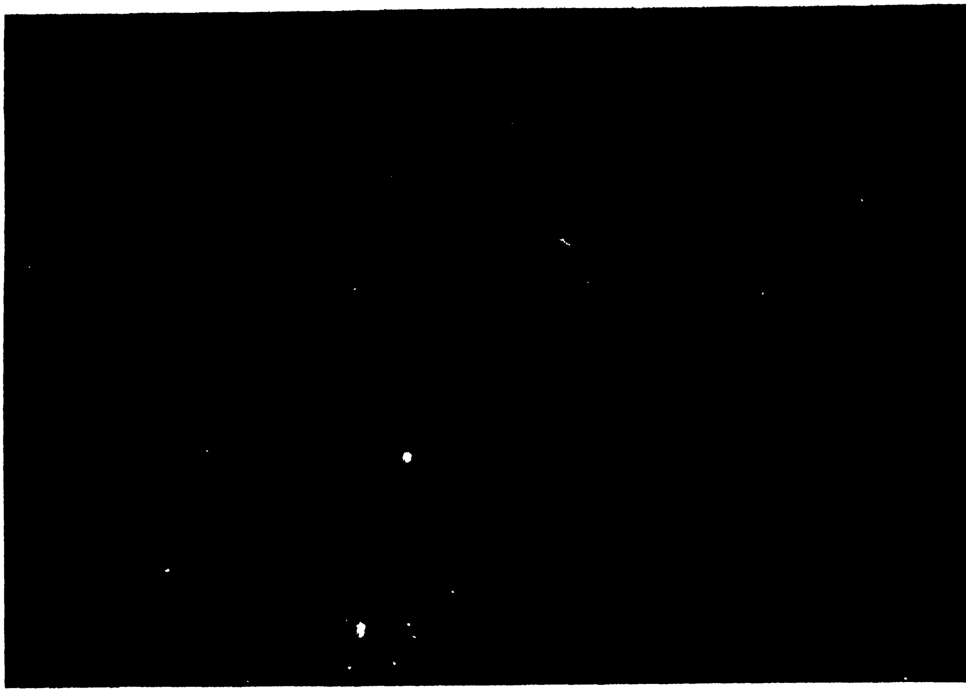
given to directing it to such ends. Scientific societies, of which there are nearly a thousand—large and small—in the United States alone, will meet again to discuss the progress and the problems in their respective fields; the association in cooperation with its affiliated societies will again present on its programs speakers of national and international reputations, and will hold scores of different sessions for reports on explorations into nearly every subject of human interest.

F. R. MOULTON,
Permanent Secretary

ANOTHER STELLAR EXPLOSION

THE brightest "new" star, or nova, seen for more than a generation has recently flared up in the southern constellation of Puppis. Professor B. H. Dawson, of La Plata, Argentina, reported his discovery to the Cordoba Observatory, whence the discovery was immediately cabled to Harvard on November 10. By November 12 the new star reached its maximum light, at magnitude 0.5, and shone for a day or two as one of the ten brightest stars in the entire sky. Many observers, of course, discovered Nova Puppis independently. Such a bright object will be detected by keen-eyed observers in spite of its adverse location as seen from northern latitudes; for New England the maximum altitude above the horizon was only about twelve degrees around 5 or 6 A.M.

The nova problem is still an outstanding riddle in astronomy. Hence the occurrence of an unusually bright nova is of great value because the most powerful spectrographic equipment may be utilized in its study. Nova Puppis, how-

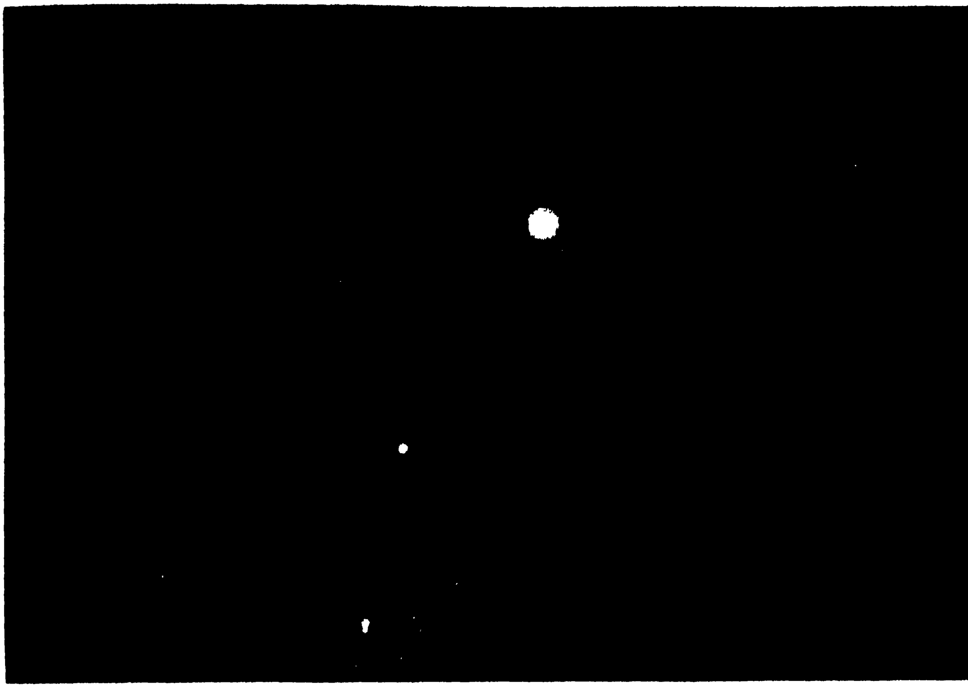


REGION OF NOVA PUPPIS BEFORE THE OUTBURST
THE SMALL WHITE ARROW INDICATES THE POINT WHERE THE NOVA APPEARED.

ever, demands attention for still another reason. It appears to be a *hybrid*, intermediate in class between the ordinary novae and the supernovae. An inspection of older Harvard photographs taken at the South African station reveals no trace of a stellar image in the position of the sky now occupied by Nova Puppis. The nova, therefore, increased in brightness by at least a factor of a few million times, how much more we can not say. Ordinary novae flare up in brightness by a factor of a hundred thousand times, more or less, while for supernovae the increase is not certainly known but may be of the order of a hundred million times.

The light curve of Nova Puppis, on the other hand, is more typical of an ordinary nova than of a supernova. The brightness fell at an average rate of about a third of a magnitude per day for the first two weeks after maximum light. Most supernovae decrease in brightness more slowly than this, while some novae decrease more slowly and others more rapidly. In any case, Nova Puppis faded below naked-eye brilliancy in early December and will continue to fade for many months or a few years. Large telescopes will probably be required for its observation by the time that its light becomes constant. The above-mentioned observations of brightness were made by the American Association of Variable Star Observers and compiled by Mr. Leon Campbell.

The explosional velocities shown spectrographically by Nova Puppis are normal for ordinary novae. Professor Dean B. McLaughlin, of the University of Michigan, reports expanding shells of hydrogen and ionized iron, titanium and magnesium with velocities of the order of 500 miles per second. The expansional



NOVA PUPPIS AS IT APPEARED NEAR ITS MAXIMUM LIGHT

velocities for supernovae appear to be of the order of 3,000 miles per second.

From studies of previous novae, such as Nova Herculis, which in 1934 became nearly as bright as Nova Puppis, or Nova Aquilae, which in 1918 became even brighter, we may visualize the explosion as follows: for reasons unknown a star like the sun in brightness but not in character suddenly blows off its outer atmosphere. The expanding gases, consisting of ordinary metals and gases, remain opaque at a surface temperature of some 10,000° K until they have traveled the order of the earth's distance from the sun. Maximum light occurs near this time, only a very few days after the outburst. Then the expanding layers or shells become increasingly transparent and rarefied as the total light falls. At the same time the exceedingly hot but relatively small nucleus of the star heats these rarefied gases and raises them to higher stages of ionization until we can observe no continuous spectrum but only the bright-line spectrum, essentially fluorescent as in a planetary nebula.

Sometimes these tenuous envelopes can be seen directly as nebulous clouds moving slowly away from the star. Finally, after several years, only the faint (but hot) star remains visible, apparently in its pre-nova condition, little affected by the loss of probably a few earth masses of material.

We may well hope that Nova Puppis, whose recently observed explosion probably occurred some thousands of years ago, will provide some key as to the cause of its outburst. Did the star become internally unstable as it radiated away its store of energy, or did some external mechanism such as a planetary or stellar collision set off or produce the explosion?

FRED L. WHIPPLE

NEWTONIA AT BABSON PARK

SIR ISAAC NEWTON, who was born on Christmas in 1642, lived in London from 1710 until 1725, two years before his death. This was the period of his life in which he was at the height of his fame and the recipient of universal homage and many honors. His London home contained his choicest possessions—library, pictures, medals and numerous documents in his own handwriting.

Good fortune and the vision and initiative of Mrs. Roger W. Babson have secured for America the actual fore parlor of Newton's London House, together with original books from his library, manuscripts, furniture and other memorabilia. They are in the library of Babson Institute, located at Babson Park, a suburb of Boston.

The good fortune consists, in part, of the fact that Newton's house was preserved until 1913 and, in part, of the fact that as it was about to be demolished it was removed and preserved by English antiquarians. Then, in 1937, Mrs. Babson while on a visit to England learned of its existence and at once purchased the fore parlor and arranged for its removal to its permanent house in the library of Babson Institute, which was dedicated in October, 1939. This library now contains all the editions of the works of Newton and their translations, collected by Mrs. Babson during many years of travel and research, original books and documents from his library, material and memorabilia relating to his life and times, and the actual room in

THE RESTORATION OF THE FORE PARLOR OF NEWTON'S HOME
A COPY OF A PAINTING OF NEWTON BY J. VANDERBANK HANGS ABOVE THE FIREPLACE. THE DESK, CHAIRS AND TABLE ARE EXACT REPRODUCTIONS OF ONES WHICH NEWTON USED.

THE HOME OF SIR ISAAC NEWTON

which he worked during his residence in London.

It is believed that Newton's house was built shortly after the Great London Fire in 1666. The restoration of the fore parlor contains the original warm English pine, now mellowed with age; across its threshold fell the shadows of Halley and Locke and Sir Christopher Wren. Here also came Addison and Swift and other English and foreign men of learning and letters. Here are faithful reproductions, made from inventories and careful drawings and descriptions, of the desk at which Newton sat and corrected the manuscripts of the later editions of the immortal "Principia," and of other pieces of furniture. Here are chairs such as those his visitors occupied while they discussed with him questions of science or problems of state.

Thus into the Babson Institute library in the town of Wellesley, located in what was the *new* England of Newton's day has gone this ancient room. At its dedication the library came into possession of a cultural heirloom which can never be duplicated. Its quiet and scholarly walls have held the words of famous men of one of England's most brilliant periods.

Historical societies of individual admirers of Newton may set up other memorials of Newton. They may be more resplendent, but this venerable room enshrines the memories of the last days of the greatest scientific genius of the English people.

It is particularly significant, therefore, that in this year 1942 when the whole civilized world is trying to roll back the tide of barbarism and savagery that threatens to engulf us, we should pause and consider the life of this man who was born three hundred years ago. He offers us a hope that man can survive and go on to greater wisdom and higher things—and offers us that hope at a time when the outlook for mankind is dark indeed.

Of the great works of Newton, the

NEWTON EXPERIMENTING
WITH THE COMPOSITION OF LIGHT.

Babson collection includes nearly all editions. It has all the editions of the "Principia," including the scarce second

NEWTON'S LAST LONDON RESIDENCE
AT ST. MARTIN'S STREET, LEICESTER SQUARE.

issue of the first edition. One copy of the first edition has notes in Newton's handwriting. There is also a third edition with wide margins, specially bound in red morocco with hand-tooled gold decoration on the cover. This was prepared especially by Newton in his latter years for presentation to the leading scientists and mathematicians in England and on the Continent. There were only twelve copies of this edition and only

TITLE PAGE, NEWTON'S "PRINCIPIA"
PHOTOGRAPHED FROM A COPY OF THE FIRST EDITION, PUBLISHED IN 1687, NOW IN THE BABSON LIBRARY.

seven of them are now known to be in existence. Most of the translations and commentaries are in the collection.

The collection has the edition of 1736 translated from the original Latin by John Colson. It also has the translation of 1737 by an unknown translator, and the French translation of 1740. It also includes Raphson's "History of Fluxions," published in London in 1715, in Latin.

All editions of "Opticks," both En-

glish and Latin, are in the collection; a second edition was in Newton's library and it contains addenda and corrections in his handwriting. It also includes Coste's and Marat's translations into French. Included are "Optic Lectures Read in the Public Schools of the University of Cambridge" by Newton and translated into English from the original Latin in 1728. Papers by Sir Isaac printed in the *Philosophical Transactions* of the Royal Society of London are included.

Many an American has stood with bowed head before the tomb of Newton, in Westminster Abbey, where lie buried the noblest and greatest English dead, and has read with awe and reverence its inscription (in free translation from the Latin), "Mortals, congratulate yourselves that so great a man has lived for the honor of the human race." In the library of Babson Institute a much larger number of Americans will be inspired by the sight of the very room in which Newton lived and worked during the most honored years of his life.

C. J. H.

IN THE BEGINNING

PERHAPS the most interesting by-product of the theory of the expanding universe, a theory which Dr. Hubble has discussed from the observational point of view in his article appearing in this issue, has been the conclusion that the physical universe had its origin some two billion years ago. This is putting Creation back far beyond the period of six thousand years in which most good men believed until within about two generations; and far beyond the fifty or sixty million years for the age of the earth as the maximum permitted by Lord Kelvin and other physicists until this century was well on its way.

The argument for the origin of the physical universe about two billion years ago is about as follows. The spectral lines of very distant stellar systems are found by observation to be displaced from their normal positions toward the red end of the spectrum by amounts that are proportional to the distances of the objects from which the light came. Such displacements of spectral lines would be produced by the recession of the sources of light relative to the receiver. Hence the observed displacements find an explanation in the theory that the galaxies of stars are receding from one another with relative velocities that are proportional to their distances apart.

Accepting this as the correct and only possible explanation of the observations, it follows that on looking backward in time we find these great aggregations of stars progressively nearer and nearer to one another, and that about two billion years ago these myriads of galaxies, each consisting of hundreds of millions or billions of suns, were crowded into a space no larger than that now occupied by our own stellar system. Then what? As we go backward in time was the space occupied by the physical universe ever smaller and smaller and the average density of matter ever greater and greater, the former approaching zero and and the latter infinity? No! That pathway has not been followed by those who have been interested in these phenomena. As men have often done in the past, they escaped unanswered and unanswerable questions and secured peace of mind by inventing a Beginning, a Creation.

By this invention peace of mind has been secured, but only for a moment and at a high price. It has been only for a moment because Dr, Hubble, who discovered the phenomenon we are considering, found on a recent and more critical

and exhaustive examination of the observations on which the bizarre conclusion of the "exploding universe" was based that the data are not exactly in harmony with the theory that the displacements in the spectral lines are due to velocities of recession that are proportional to the distances of the radiating aggregations of stars. Unless further investigations disprove Dr. Hubble's conclusions, the peace of mind afforded by the invention of a Beginning is lost. It deserves to be lost because it was won at the price of ignoring the possibility of other explanations of the observed displacement of the spectral lines of distant galaxies. It deserves to be lost because scientists need to be taught over and over again by experience the lesson that the whole history of science should teach, namely, that they should always be alert for many different interpretations of phenomena, for finality is never reached.

There is, in a sense, a complementary theory to that of Creation, namely, the theory that the universe is doomed to final stagnation and death. Certainly the stars and other luminous bodies are pouring their energy out into space at the expense of their masses. Although the wasting away of a star's mass by radiation is a very slow process in terms of human or even geological history, yet so far as can be seen at present it goes on relentlessly and is never generally reversed. Hence both energy and mass are being scattered through the vast abysses of intergalactic space which light can traverse only in millions and hundreds of millions of years. As the scattering goes on it takes place ever more and more slowly with the result that it will never be completed, though that end is always being approached. In this respect it is different from Creation which, according to the theory under consideration, began with an explosion of a cosmic scale. It should be remarked, however, that if the mass of the universe is infinite no eternal night need everywhere follow, though it is not easy to show precisely why not. Moreover, it is quite likely that open and penetrating minds will discover many other possibilities not now dreamed of.

It is a strange characteristic of the scientist, as well as of the unreflecting, that he often, perhaps generally, finds comfort in the belief that there was a definite beginning, and often in the belief also that there will be an end, of the physical universe; but he clings to a faith that there is within him some immortal spark that will never fade and pass away. There have of course been many exceptions; indeed, nearly two thousand years ago the Roman poet-philosopher Lucretius, in *De Rerum Natura,* thus questioned this faith, according to the rendering of Mallock:

What! Shall the dateless worlds be blown
Back to the unremembered and unknown,
And this frail Thou—this flame of yesterday—
Burn on, forlorn, immortal, and alone?

F. R. M.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1943

RECENT ADVANCES IN OUR KNOWLEDGE OF THE VITAMINS

By Dr. C. A. ELVEHJEM

PROFESSOR OF AGRICULTRAL CHEMISTRY, UNIVERSITY OF WISCONSIN

If one examines a present-day chemical catalogue the following compounds may be listed under the heading of vitamins: vitamin A alcohol, carotene, vitamin D_2, vitamin D_3, α-tocopherol, 2-methyl-1,4-naphthoquinone, l-ascorbic acid, thiamine hydrochloride, riboflavin, nicotinic acid, pyridoxine, calcium pantothenate, choline chloride, crystalline biotin, p-aminobenzoic acid, inositol, etc. Those who have not followed closely the vitamin literature may be surprised at this array of compounds and wonder how they are related to practical nutrition.

In the first place it is evident that tremendous advances have been made in our knowledge of the chemistry of the vitamins since it is not so long ago that a crystalline vitamin was a laboratory curiosity and an amount of a pure vitamin sufficient to feed a group of rats for several weeks cost hundreds of dollars. To-day we think nothing of purchasing many of the vitamins in good-sized bottles or even in kilogram lots.

Vitamin A alcohol, carotene, vitamin D_2 and vitamin D_3 are the pure forms of the two oldest and best-known fat soluble vitamins. They are still made from natural products, since neither of these vitamins is being produced synthetically, although considerable progress has been made recently in developing methods for producing synthetic vitamin A. Much of the vitamin A in natural diets is supplied by milk and milk products and green vegetables and for many years any supplementary vitamin A was added as fish-liver oils. Highly active concentrates of both vitamin A and carotene are now used for fortification of foods and in vitamin capsules. Vitamin D was similarly supplied by fish-liver oils but recently refined sterols are activated for the production of vitamin D concentrates. The pure preparations are valuable as standards for the determination of these vitamins in foods. For many years pure beta carotene has been used as the standard but it is also important to have pure vitamin A available since it is now rather definitely established that carotene is not assimilated as readily from the intestinal tract as the vitamin A alcohol. Vitamin D_2 is used as the standard for vitamin D although it is well known that in the chick vitamin D_3 is much more active than vitamin D_2. In the human the difference in activity is negligible. This brief discussion of these two well-known vitamins brings out a fact which is true for most of the vitamins, namely, that several related compounds may have similar biological action but the degree of their activity varies. In the case of vitamin D at least 10 different compounds are known to

have antirachitic properties, but vitamins D_2 and D_3 are the most important ones. It is also interesting to compare the actual weight of the compound needed to produce the desired effect in the case of different vitamins. The human requirements for vitamins A and D are generally expressed in International Units but on a weight basis 1.5 mg of vitamin A or 3 mg of carotene will meet the daily vitamin A requirement, while only .01 mg of vitamin D is an adequate daily intake of this vitamin.

Alpha-tocopherol is a light yellow viscous oil and is now available in synthetic form as the most potent source of vitamin E. Again other tocopherols show vitamin E activity, but the alpha form is the most active. Although vitamin E was first recognized as a vitamin essential for normal reproduction in rats, it now has a much wider significance. As early as 1928 it was observed that suckling rats born of mothers which had received just enough vitamin E to permit successful gestation developed a characteristic paralysis. Muscle dystrophy has been produced in many different animals by depriving them of their vitamin E intake. The muscle dystrophy is accompanied by an increased excretion of creatine and an increased rate of oxygen uptake in the muscle tissue. The cure of nutritional muscular dystrophy in animals is abundantly proved, but vitamin E therapy in neuromuscular diseases in humans has not been too successful. The availability of alpha-tocopherol will allow more extensive study of human cases. At present there is no indication that natural diets are low in vitamin E and therefore it has no value in the fortification of foods.

The compound 2-methyl-1,4-naphthoquinone probably does not exist in nature as such, but still it shows greater vitamin K activity than any of the natural forms of this vitamin. The original work on vitamin K was quite independant of any human disorder. In 1929 Dam observed that chicks raised on certain artificial diets became anemic, developed intramuscular hemorrhages and showed a marked increase in the clotting time of the blood. He concluded that the disease was due to a lack of hitherto unknown dietary factor and vitamin K was used to designate the factor. During the period 1935–1940 assay methods involving the chick were developed and vitamin K_1 and K_2 were isolated and their structures established. Almquist first discovered the vitamin K activity of the simple quinone 3-hydroxy-2-methyl-1,4-naphthoquinone and later Ansbacher and Fernholz showed 2-methyl-1,4-naphthoquinone to be 3 to 4 times as active in the chick assay as vitamin K_1. Both K_1 and K_2 contain the naphthoquinone nucleus but a longer side chain makes them soluble in fat. The compound, 2-methyl-1,4-naphthoquinone, now called Mendione, is used as a standard in vitamin K assays and in clinical work. Certain derivatives of Mendione are now available which are more soluble in water than the original compound. It is very difficult to produce a vitamin K deficiency in mammals or humans by dietary means but this vitamin is of distinct value in maintaining a normal prothrombin level in new born infants and in adults with decreased intestinal absorption such as obstructive jaundice. Under normal conditions there is considerable synthesis of vitamin K by the bacteria of the intestinal tract and therefore the supply of this vitamin in the normal diet is not as important as in the case of other vitamins.

l-ascorbic acid or vitamin C has the distinction of being the first vitamin to be produced in synthetic form. The compound was actually isolated in 1927, but five years passed before the biological activity of the compound was recognized. In 1932 King and Waugh dem-

onstrated the identity of vitamin C and hexuronic acid, now known as ascorbic acid. The importance of a specific configuration in a biologically active compound is clearly illustrated in the case of vitamin C, since l-ascorbic acid is highly active but d-ascorbic acid is completely inactive. To-day ascorbic acid is so readily determined by chemical methods that it is difficult to realize that we used to have to rely upon the long and tedious guinea pig assay. This vitamin is widely used in clinical work but its use in fortification programs is rather limited, for several reasons. Vitamin C is easily and cheaply supplied by fruits and vegetables in the diet and it is easily destroyed when mixed with many natural products. The synthetic material has had an interesting application in farm practice during the past few years. Although cattle are able to synthesize sufficient vitamin C to meet their own requirements, the amount of synthesis is greatly reduced in vitamin A deficiency. In such cases the injection of vitamin C has had a very beneficial effect on the sterility which develops.

Thiamine hydrochloride is a white crystalline substance readily soluble in water and possessing a yeast-like odor. Due to the well-known efforts of R. R. Williams and cooperating manufacturing chemists this important compound may now be purchased at a wholesale price of 40 cents per gram. The price is of even greater significance when we realize that one gram of thiamine is sufficient to supply the requirement of one adult for almost two years. We used to teach that the vitamin-carrying foods was the costly part of our diet, but this most encouraging experience indicates that the only limitation in making vitamins readily available to large groups of the human population is the original identification and isolation of the vitamin.

In foods and in animal tissues thiamine occurs both in the free form and as cocarboxylase. In this latter form it functions in the living cell as a coenzyme in carbohydrate metabolism. Thiamine can be oxidized to thiochrome, which shows fluorescence and the degree of fluorescence produced may be used as a measure of the amount of thiamine in food. This simplified procedure has been of the greatest value in establishing the thiamine content of common foods. In fact, our knowledge of the distribution of thiamine in the wheat kernel was very limited until this improved method was made available. Since almost 90 per cent. of the original thiamine in a wheat kernel is lost during the milling of the patent flour, white flour and bread is now being enriched with thiamine to a level of 1.6 to 2.5 mg per pound of flour. In order to meet this demand and other requirements, tons of synthetic thiamine are now produced annually in the United States.

It is most encouraging to find riboflavin listed with the other vitamins, since its structure is probably the most complex of the water soluble vitamins and it still can not be manufactured fast enough to meet the demand for it. Its addition to enriched flour has been postponed several times by the Federal Security Agency because of an insufficient supply. In spite of the difficulty in producing sufficient quantities the price has steadily decreased. Riboflavin was first recognized as a component of an important respiratory enzyme and has since been found to be related to several enzyme systems. Its importance in human nutrition was not recognized until 1938, but since that time significant advances have been made regarding the value of this vitamin in maintaining optimum health. This vitamin is rather widely distributed in foods, but the most reliable sources are milk, meat and vegetables. In certain areas of this country the consumption of these food

products is low enough to allow the development of a riboflavin deficiency. The use of pure riboflavin in these areas is therefore justified at least as an emergency measure.

Nicotinic acid has been available as a chemical compound for over fifty years but its nutritional significance did not become evident until 1937. Nutritional workers experienced considerable difficulty in studying the anti-pellagra factor because a syndrome similar to human pellagra could not be produced in any of the laboratory animals except the dog. In 1937 it was shown that nicotinic acid would cure black-tongue in dogs and very shortly thereafter the value of this compound in the treatment of human pellagra was definitely established. It is now possible to explain the earlier difficulties because the rat does not need nicotinic acid preformed in its diet, while the dog and the human do require this factor. Nicotinic acid is a very simple compound and functions in the animal body as a constituent of certain coenzymes. At first it was necessary to depend upon assays with dogs for the determination of the nicotinic acid content of natural foods, but within the past year or two both microbiological and chemical methods have been developed which are very reliable. Many of our natural foods are not rich sources of nicotinic acid and diets devoid of meat are likely to be deficient in this factor. Of the cereals, wheat is the best source but like thiamine, about 90 per cent. of the nicotinic acid in the original kernel is lost during the milling process. That is why nicotinic acid or niacin is included as one of the ingredients in enriched flour and bread.

During the period 1938 to 1940 two additional compounds, namely, pyridoxine and calcium pantothenate, were added to the group of B vitamins. The earlier work on pyridoxine depended upon its ability to prevent a dermatitis in rats which was observed during attempts to produce pellagra in rats. Pantothenic acid was recognized as an essential factor in the animal through work with the chick. To-day we know that both of these compounds play an important role in the nutrition of a variety of animals. There is little doubt about the need for these factors in human nutrition although specific diseases have not been associated with their lack in the diet. The reason for this is undoubtedly due to the fact that these two factors are widely distributed in natural foods and that processing of natural foods does not decrease the amount of pyridoxine and pantothenic acid to the same extent that thiamine and niacin are decreased.

Choline is another compound that has been known by biochemists for many years as a constituent of lecithin. Its nutritional significance was not recognized for a long time, but we now know that choline is essential in the diet of the rat, dog and the chick. Clinical work on choline is very limited although recent studies indicate that it may have some value in treating liver cirrhosis.

If rats or dogs are placed on a purified diet consisting of sucrose, casein, a salt mixture and a small amount of fat, together with the pure vitamins discussed thus far, the animals will grow fairly well and reproduce. These results have led some workers to feel that all the known vitamins have been identified. However, there are a number of indications which suggest the existence of other factors. If a little liver or yeast is added to the above ration, an improved rate of growth is obtained. If a bacteriostic agent such as sulfaguanidine is added, the need for additional vitamins can easily be recognized. However, the best evidence comes from work with other animals. If chicks are fed the above ration plus a small amount of purified liver extract the animals develop typi-

cal dermatitis. This dermatitis can be cured by the addition of biotin.

Biotin was first isolated in 1936 and recognized as a growth factor for microorganisms. Later György and du Vigneaud suggested that biotin was identical with the factor which prevented egg white injury in rats. We now know that under normal conditions sufficient biotin is synthesized in the nutritional tract of rats to meet their requirement, but when raw egg white is added to the diet the assimilation of biotin is prevented. In the chick, however, the synthesis does not take place to any appreciable extent and biotin must be supplied preformed in the diet. In order to produce a biotin deficiency in the chick it is necessary to supply a small amount of liver extract in addition to the purified vitamins. If biotin is added to the purified vitamins the factor or factors in the liver extract can be studied. At present these additional factors have not been isolated but one of the factors is undoubtedly related to a factor named folic acid by R. J. Williams which is essential for the growth of lactic acid bacteria. When folic acid can be supplied in pure form it will be possible to study the remaining factors in liver extract and yeast. Thus the chick has proven a very valuable laboratory animal in studies on the newer vitamins.

Work with mice has demonstrated the importance of inositol for the normal development of this animal. Again inositol has been known as a chemical compound for many years, but its specific importance in nutrition was only demonstrated through the use of the mouse. Woolley has shown that inositol may be synthesized in the intestinal tract of the mouse by certain types of bacteria. Thus the requirement of different species for inositol may depend upon the degree to which this synthesis may occur.

Another factor which was first recognized through its effect on bacterial growth and which now shows indication of a vitamin-like action in animals is the rather simple compound, para-aminobenzoic acid. It has been isolated from yeast and is rather widely distributed in natural foods. Ansbacher has shown it to have a slight promotion of growth in chicks and anti-gray hair activity in rats. More recently reports have been made that it has a positive effect on the pigmentation of hair in man. Para-aminobenzoic acid has a specific counteracting effect on the bacteriostatic action of all the sulfa-drugs.

The guinea pig still fails if fed a purified diet containing all the above vitamins. Several natural products must be included in the diet before normal growth is obtained. There is, therefore, ample evidence that we need to continue our search for additional factors.

From this brief summary of the known vitamins it is evident that at the present time the vitamin requirements of man can be expressed in chemical terms to a greater extent than ever before. This fact may lead some individuals to sit back with a sense of security and suggest that nutritional deficiency disease will no longer be a problem in this country. This reaction is, of course, erroneous since we have only made the first step in eliminating nutritional disorders. The synthetic vitamins are merely one set of tools for building a firm and lasting foundation for adequate nutrition for all.

To be sure the synthetic vitamins are of great value to the clinician who must treat extreme cases of vitamin deficiency. It is no wonder that medical workers and the public in general are enthusiastic about the dramatic effects of nicotinic acid in pellagra, thiamine in polyneuritis and related disorders, riboflavin in cheilosis, vitamin K in hemorrhagic conditions, etc. However, the big problem for the medical worker is to learn how

to diagnose deficiencies especially in their early stages when therapy is most valuable. In the last number of "The Milbank Memorial Fund Quarterly" H. D. Kruse summarizes the various manifestations of nicotinic acid and vitamin C deficiencies. More summaries of this kind are needed.

It is the goal of nutrition workers to prevent the development of nutritional disorders. This can only be accomplished by a thorough knowledge of the distribution of the known vitamins in natural foods. The availability of the pure vitamins as standards has given great impetus to extended assays. Work of this kind is slow and tedious, but it is gratifying to find that the industries supplying meat, cereals, milk, fruits and vegetables are giving considerable support to these projects.

Lastly the synthetic vitamins may be used for the fortification of certain foods in order to relieve the wide-spread incidence of a specific vitamin deficiency in restricted areas of this country. This is now possible because of the low cost of some of the vitamins such as thiamine and niacin. It is futile to compare the cost of one vitamin when supplied in the form of a natural food and when supplied in synthetic form because the natural food usually carries an appreciable amount of all the nutrients, not only most of the vitamins, but such comparisons do indicate why it is possible to fortify foods under emergency conditions. For example, 10 mg of nicotinic acid may cost 700 times as much when purchased in the form of high-priced foods as it does when purchased as the pure chemical. In spite of these facts natural foods have been and will continue to be the main source of the vitamin in our diet, but enrichment programs will play their role in buffering sudden changes in the availability of natural foods.

When historians look back on the decade 1930–1940 it will be considered a period when greatest progress was made on the chemistry of vitamins. Let us hope that the decade 1940–1950 will be considered the period when the most sensible application of the available knowledge is made.

A TRUE HUMANIST

We profoundly hope and earnestly strive for a future in which a balanced education may be again possible. What all must see is that such a balance will not be determined by us alone. Our neighbors everywhere on the planet force us to take them into account. Their traditions, their ideas, their possession and probable use of power are among the permanently inescapable forces of life. We can neither wrap ourselves up in the past, and disclaim responsibility for conveying useful truth about the outside world to the coming generation nor neglect the past in our hurry to find solutions for political and social problems too complex to be resolved by simple schemes devised by the philosophers.

From the temple itself comes the assertion that the true humanist is one who is a servant of his times, using his knowledge as "a weapon and an arm not merely a liberal art." Preoccupation with "life and time and eternity" need not exclude consideration of the plainer needs of the hour with their high content of the practical, the scientific and the political. Even in our so-called material civilization science and humanism need never be in conflict among cultivated men. I have no fear whatever that our "culture" will be destroyed by a scientifically implemented war, however prolonged, if we are the victors. My only fear is that the lessons of this war will be lost in the fatigues of a post-war world in which men may again try to find security in provincial simplicities, assumptions and slogans, educational and otherwise. Education must be as intense, imaginative and experimental as the problems of the future are complex and difficult.—*Isaiah Bowman* in the Report of the President, 1941–1942, of the Johns Hopkins University.

STRUCTURE, FUNCTION AND PATTERN IN BIOLOGY AND ANTHROPOLOGY

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THE concepts of the aspects of structure and function are familiar in biology. It is proposed to examine here how far the two concepts can and cannot be applied properly in anthropology.

The terms structure and function are considerably used in anthropology, but with variable meaning. Function especially has been employed in so many and ambiguous senses that some cultural anthropologists, such as Milke, advocate its discontinuance. On the contrary, Linton has attempted to distinguish the form, meaning, use and function of cultural phenomena. Structure sometimes has its common-sense meaning, as when we speak of the structure of a canoe. Sometimes it emphasizes form; sometimes organization; as in the term "social structure" which is tending to replace "social organization," without appearing to add either content or emphasis of meaning.

At bottom, it would seem in biology, when the structures of organisms have been sufficiently analyzed, they fall into certain patterns. These patterns group or classify the organisms; and those showing the same pattern are considered not only similar, but related; that is, connected in descent. In short, one significance of structure is that it yields classification by pattern, which in turn has genetic or "evolutionary" significance; in other words, historical significance. This is of course not the only significance with which biology is concerned: physiological biology is occupied primarily with the direct interrelation of specific structures with specific functions as they exist, without other than incidental attention to how they came to be. However, in historical biology—comparative morphology, systematics, paleontology, partly in genetics—operations are explicitly or implicitly in terms of basic patterns that have historical depth.

Thus the mammalian pattern of dentition is 44 teeth: 3 incisors, 1 canine, 4 premolars, 3 molars on each side of each jaw; and this pattern—though it may be reduced and greatly modified by specialization of shape—is not violated except in the case of ancient lines of organisms, like the whales, whose total structure, as well as total functioning, is highly modified. The vertebrate pattern, at any rate above the fishes, provides for a pair of limbs at each end of the trunk. When an altered function is achieved, like flying, it is by conversion of a pair of legs into wings. In the bats and certain ancient reptiles, the flying surface of the wing is supported by a specialization of digital structure. In the birds and certain other extinct Reptilia, the wing is supported on the proximal heavy bones of the limb, with loss of its digital portions. But in no case has a vertebrate achieved flight except by functional—and structural—conversion of one of the pairs of limbs generally and presumably originally serving terrestrial or water locomotion. This is in contrast to the insects, whose basic pattern includes three thoracic segments, each provided with a pair of jointed legs and two of them with wings also. An insect accordingly flies without giving up any of its legs by conversion. Deep-seated as this insect pat-

tern is—and it has geological antiquity—it is not absolutely basic. The other arthropods are wingless but possess more than six legs in their patterns: spiders eight, crabs ten, other crustaceans, scorpions and centipedes more yet; but always with one pair only per segment. The insect pattern, therefore, represents an important modification of a still more ancestral pattern.

The idea of basic pattern has not been wanting in anthropology. Sapir articulated it most clearly. Language is the part of culture which particularly lends itself to pattern recognition, because its precision of form facilitates analysis. However, as a concept or tool, basic pattern has been used much less, and has been formulated less clearly, in anthropology than in biology. One reason is that in culture the tremendously conservative force of organic heredity is not operative; at any rate, is obviously not the direct or immediately operative factor. Cultural patterns therefore tend to be short-lived: we may trace them for a few thousand years, but not for many millions. Moreover, widely divergent cultures can and do hybridize; organisms, only within very narrow limits of relationship and descent. There is nothing in the biologic realm comparable to the fusion of Helleno-Roman and Asiatic civilizations to produce Christian civilizations; or of Sino-Japanese and Occidental culture in Japan since 1868. The tree of life is eternally branching, and never doing anything fundamental but branching, except for the dying away of branches. The tree of human history, on the contrary, is constantly branching and at the same time having its branches grow together again. Its plan is therefore much more complex and difficult to trace. Even its basic patterns can in some degree blend; which is contrary to all experience in the merely organic realm, where patterns are irreversible in proportion as they are fundamental.

However, granted the relative mutability, plasticity and ultimate fusibility of all patterns in human history, there remains no doubt that there are cultural patterns which are more basic or primary and on the whole older, and others which are more superficial, secondary and transitory. Obviously, if we wish to trace the history of human civilization—especially in its preliterate and therefore prehistoric phases—it is of the utmost importance to recognize the basic patterns and distinguish them from their secondary modifications. The older anthropology, it seems to me—Tylor for instance—made a deliberate attempt to do this. It failed, to a large extent at least, because of several related deficiencies. It tended to substitute common denominator for true pattern. It synthesized prematurely into formulations like animism and magic and totem, which are part basic pattern indeed, but in part only denominator. And, finally, it forgot that all recorded history being a series of objectively unique events whose major significance lies in their organization into distinctive patterns and not in ill-defined formulas or generalized denominations—it forgot that very probably the same held of the prehistoric and primitive part of the human story. True, we also use the word "formula" for mammalian dentition. But the mammalian dentition formula is quantitative; it is entirely precise; it is highly distinctive, in fact unique; and it has, so far as the totality of our knowledge allows us to judge, authentic historical depth and significance. In contrast, a formulation like animism or totem has none of these qualities, except historical depth, and this may prove to be an accidental denominator; even the historical significance is none too sure, especially for the totem. Whereas the relatively mutable patterns of culture are more difficult to extricate than the relatively stable ones of life, the earlier anthropology, even

though headed in a sound direction, made a premature, superficial synthesis—perhaps precisely because of its immaturity as a branch of study.

The need of more exact and deeper analysis was recognized in the next stage of our science; but with it, the synthetic impulses faded. A healthy distrust grew up for the hazy formulations of the earlier generation. If we now used them, it was of necessity; they were crutches, no longer goals. We reveled in discovering the rich diversity of forms which culture assumed. We analyzed as carefully as any historian; but we refrained, for a time, from doing any history, from probing for time depth and relative sequences. We had become shy of the sort of findings which our predecessors considered historical, or an equivalent of historical findings; but we had not yet attained to the concept of the basic pattern as a tool which inevitably carries at least historical implication, if not outright significance.

In the present stage of anthropology, two currents are flowing in opposite directions. First, there is a resumption of historic interest: analysis is continued from the preceding stage, but it is more courageously being used for constructive historical objectives, with increasing recognition of the value of the basic pattern method. It is important to remember that this approach is not wholly phenomenological and undynamic. After all, as a pattern is basic, it is determinative of its modifications: it sets the frame within which change can take place; it is one of the factors which jointly produce what happens. The charge sometimes leveled that history is only a series of facts, unorganized but for their time order and meaningless except in themselves, proves only one thing: that those who so hold have, through over-preoccupation with other interests, a blind spot for the historic approach, whether in biology or in human affairs, and fail to recognize the significances which inevitably attach to pattern organizations.

The other current in contemporary anthropology aims at a sort of physiology of culture and society. It is concerned with extricating process, with uncovering dynamics. It comprises those who accept the name of functionalist, and the like-minded who insist on working with present-day phenomena and have little concern with the past. They hope to move from the contemporary directly into generalization, perhaps into universals. It is true that knowledge of living phenomena is inevitably capable of being fuller than knowledge of former ones. A physiology of cultural and social phenomena is presumably possible and would certainly be extremely important. The danger is in confusing a goal with an attainment. And to be ambiguous on this distinction is specially tempting to those unduly interested, for scientists, in personal success. The public at large is unaware of the fact that in biologic physiology selective experiment with control is the essence of method, but that in social physiology it is selection alone that is chiefly possible, both experiment and control being as yet scarcely devised, if devisable at all. Also, with the focussing on the living, time perspective goes out; and, with this, the best opportunity of recognizing the fundamental patterns involved. In fact, it would appear that the area of which there is immediate consciousness in cultural and social change is the special modifications which are taking place at the moment, while consciousness of the more enduring and basic structural features tends to be lost sight of—both by those desiring to bring about change and those interested in studying it. It is accordingly no accident that Malinowski avowed an antihistorical bias; that Radcliffe-Brown admits the historical approach but confines it to documented data and cites as

his exemplars of historical anthropology chiefly the precursors of Tylor; and that Warner avoids a quarrel but actually considers only recent antecedents, and those mainly in order to heighten background contrast.

All the functionalists put unusual emphasis on integration. Either this amounts to making explicit what has always been taken for granted, or, when most rabid, it comes to elevating integration into a final principle which explains everything and thereby chokes off farther inquiry. It is very much as if physiologists were to proclaim as their ultimate finding: see how the human body hangs together! See how harmoniously it works!

There is of course no valid quarrel with a primary interest in function in the socio-cultural field, provided such interest is not stretched into a superiority dogma or panacea. It is as one-sided, and ultimately sterile, to be exclusively preoccupied with structure as with function. This has been long since learned in biology, and will have to be learned in anthropology.

One concept shared by biology and anthropology is that of convergence. For instance, the pseudo-vertebrate eye, beak, and backbone of the molluscan squid. Trees, and again vines, have over and over originated independently in separate families of plants; so has the habit of male and female sex-organs being borne separately—alternatively—by different plant individuals. Snakes move like worms, and whales swim like fishes. Flight has been attained separately by insects, reptiles, birds and the mammalian bats, not to mention man, if we transcend the organic level. Almost exactly parallel socialization has been attained by the termites, who are descended from the roach stem, and by the ants who are Hymenoptera. There are thousands of instances, some of them highly special, like the horny forehead shields with which access to the burrow is blocked both by some toads and by some termite warrior castes.

Now what is characteristic of all organic true convergences is that they are analogues, not homologues. There is a similarity of function, but a dissimilarity of structure. The dissimilarity is usual even in the converged organ or organs, invariably present in the total structure of the organisms. In short, it is because the basic patterns differ that the similarity is convergent. The histories are unlike, the secondary results are like; especially as regards function, use, and behavior; though the like results need not be superficial or trivial—in fact may be accompanied by pervasive modifications of the organism.

While we have long recognized convergence in anthropology, we have tended to deal chiefly with limited, specific cases in which reasonable proof was not too difficult to bring. Probably we have been too unsure of fundamental pattern structure in the protean field of human history to venture to class larger phenomena, corresponding to arboreal habitus, flying, crawling, socialization, either as convergences or as historic pattern persistences. This is certainly a matter in which anthropology is backward. But it is clear that progress can ensue only in the degree that we learn to dissociate patterns into basic and derivative or modificatory ones. This is obviously going to be harder in the field of culture than it has been in biology; but precedent should at least encourage the attempt.

One fact may help. Organic convergences not only always involve function strongly, but their similarities are easily recognized; lay observation, commonsense observation suffice to recognize trees, flight, socialization, and the like. This suggests that long recognized, frequently recurring phenomena of culture are likely to be the ones among which our

broad convergences are to be found. As examples might be mentioned the clan, totem, cross-cousin marriage, the mother-in-law taboo, potlatch, feudalism. As regards several of these, multiple causations and origins have for some time been advocated on specific associational grounds. Other possible examples are taboo, sacrifice, kingship, urbanization, writing, navigation, secret societies.

As a boy I got hold of a popular natural history, probably reprinted from an original several generations old, which classified animals into Schal-thiere, such as clams, lobsters, turtles, and armadillos; Kriech-thiere which included worms and snakes; and so on. The wonder is that such a work was still in circulation to come into the home and hands of anyone born in the last quarter of the nineteenth century. The classification is logical, naïve, and essentially functional. Shells, it is true, are nominally structural, but their real likeness is confined to their protective and defensive function. Function, apparently, is what the pre-scientific mind first takes hold of. Analysis into structure comes later, because its implications, its resultant significances, are not readily visible: it tends to pass as aimless antiquarian idling.

Now we have done enough analysis in anthropology to have good reason to believe that the recurrent phenomena which we loosely call feudalism, clans, cross-cousin marriage, etc., have polygenetic origins; and therewith the inference is near that they are merely derivative and not basic patterns. It seems that we might do well to avow this inference more explicitly; and at the same time search more rigorously for patterns that are basic. This is not as easy as in biology, where we can at least begin by laying a specimen on the table and cutting into it with a knife, and then bringing up the microscope and reagents when needed. If our search were as simple as that, anthropologists would have got farther than they have. But, granted the difficulties, have we nevertheless tried as wholeheartedly as we might?

Two endeavors are indispensable in such search for basic patterns: analysis and comparison. Analyses we do sufficiently well. For some forty or fifty years there has been produced an increasing number of monographic, analytic studies of tribal cultures, sufficiently detailed in many cases, not always inspirational, but mostly competent and useful. It is in comparison that we hang back; perhaps in undue fear that all broadly comparative work will suffer the stigma of the old comparisons which were designed to discover universals. When modern anthropologists make comparative studies over a wide range, these tend to be limited to items, such as the spear-thrower or oil lamps, rather than to whole cultures or systems. In all this, there is manifest a lack of courage about attacking problems that could be labelled constructively historical. But are we going to be deterred forever because there have been simplistic speculators who constructed pseudo-histories?

One criterion will help. With a valid basic pattern, its various manifestations show a point-for-point correspondence. Not that every mammal must have 44 teeth of four shapes; but such teeth as it has must correspond to particular ones of the 44; and once they do, the greater their modification from the general or original shape—like the elephant's incisor tusks and successive molars—the more interesting are their fit, adaptation, and history. In comparative linguistics, indeed, which is historical linguistics, such as Indo-European, Semitic, Bantu, this insistence on point-for-point correspondence has successfully become a cardinal principle of method. Culture history is no doubt more difficult; but there is every reason to believe that the principle applies.

Perhaps it is time that I cite some

examples of basic patterns in culture. They are of course surest where cultures have been documented for a considerable period. Hebrew-Christian-Mohammedan monotheism seems a good illustration; and a rich one, if we remember all its diversifications into religions, churches and sects. We know that the three "religions" are historically connected: they are outgrowths of one another. We can also define the pattern: a single deity of illimitable power, excluding all others except avowed derivatives, and proclaimed by a particular human vessel inspired by the deity. If we contrast with this the supreme deities of other religions, philosophical and primitive, we find them invariably lacking one or more of the characterizing features—usually all three. These other supreme deities, accordingly, are analogous convergences only.

Another example is the alphabet, as set off from other methods of writing. All alphabetic writing—that is, graphic symbols denoting the smallest acoustic elements of speech, but no symbols of other kind—has spread from a single origin in Western Asia about three thousand years ago. And there is point-for-point correspondence in all the manifold varieties of alphabets. Aleph, beth, gimel, daleth, correspond to alpha, beta, gamma, delta, and to A, B, C, D. Where there are changes of shape of letter, or of its sound value, or its position, these can be accounted for, at least in the overwhelming majority of cases, and lead us back to the original pattern. For instance, we know why, how, and when C came to replace G as the third letter in our own form of alphabet, and W was added.

Such a pattern, or our monotheistic one, is really a system which extends across cultures, and not a culture itself. It is possible that the same will hold true generally for all associations or complexes of cultural phenomena which fall into basic patterns. They represent pure inventions, or a series of inventions, corresponding more or less to mutations or series of mutations in organic nature. The word mutation is here used not in any specific sense which it may have in genetics with reference to a particular mechanism but as a generic label to indicate any radical, drastic, or significant change in hereditary type.

By contrast, systems of writing like the Egyptian, Cuneiform, Chinese do not share any point-for-point correspondence either with the alphabet or with one another: neither in the shape, value, nor order of their characters. So far as they are similar—in being pictographic and ideographic and syllabic—they are alike only in general function, not in specific structure; and they represent analogical convergences. What they have in common, such as the tendency to represent the sounds of speech by a sort of punning—the rebus method—and the tendency to deal with syllables rather than elemental sounds, is due presumably to psychological factors of the human inherited constitution, and therefore really outside the level of culture as such. Just so, certain generic features common to organisms which share say an arboreal habitus, or a swimming or flying one, are conditioned by mechanical factors to which the organisms adapt themselves.

When it comes to the material or technological aspects of culture, physico-chemical factors similarly impinge on culture. That bronze is composed of copper and tin, and that it is harder and casts better than either metal alone, are physico-chemical facts. Consequently, the mere fact that ancient Mesopotamia, China, and Peru made bronze is of no relevance to the problem of whether their bronze arts belong to the same or different patterns; that is, whether they are genetically connected or separated. That must be determined from specific cultural features, such as non-compul-

sory techniques in the metallurgical process, the forms cast, and the like. With these features considered, it becomes highly probable that Mesopotamian bronze and Chinese bronze are slightly variant manifestations of one pattern, but ancient Peruvian bronze represents a separate pattern and origin. For instance, Mesopotamia and China used bronze for swords and for ritual vases or other vessels; Peru did not.

Plow agriculture constitutes another example of a basic pattern. This pattern comprises at least three essential features: the plow itself; animals to draw it, which of course must be domesticated; and food plants of such a nature, like barley, wheat, millet, that they can be profitably grown only by broadcast sowing, which in turn involves fields of at least fair size, as compared with gardens. Still other features have become associated, such as the use of the dung of the animals as fertilizer. The plow is generally considered to have been an unrepeated invention, whose precise time, place, and circumstances we do not know, though it took place in the last Stone Age and probably in or near southwestern Asia, and spread along with cattle, with barley and associated plants, and usually with manuring, to all those parts of Europe, Asia, and Africa in which it was used in 1500. Native America also evolved a highly developed system of agriculture on which we of to-day have drawn for important loans. But native American agriculture belonged to a radically different pattern. It did not know the plow. It did not use draft animals, though it had domesticated ones like the llama. It did not sow broadcast but planted by hand and cultivated in hillocks. It totally lacked wheat, barley and their associates, substituting for them a series of others of which maize was the most wide-spread and principal. And it either did not fertilize at all or it used fish. It has therefore long been the conclusion of conservative, non-speculative students that New World agriculture had an origin and a history entirely separate at least from Old World plow agriculture. In short, we have two patterns and two histories.

Agriculture as such I would not call a pattern, but rather a common denominator. Numerous primitive peoples in Africa, Asia and Oceania farmed, planting with hoes or digging-sticks, without using associated animals, and raising root-crops, fruits, and even some cereals like rice or sorghum. We are not able to affirm whether all this farming or gardening had a single origin or several. It is probable that plow agriculture represents an "invention-mutation" added to some phase or other of this more primitive gardening. But we cannot say at present to which phase, any more than we know whether the phases were historically connected or independent developments. In brief, plow agriculture is a specific phenomenon, or set of associated phenomena, like mammalian dentition; whereas agriculture is rather a generalization, or concept, logically definable indeed, but rather too vague, variable or amorphous to serve as a solid foundation for a scientific structure; just as concepts like shellfish or arboreal habitus or aereal locomotion have proved unserviceable for primary scientific classification.

A given trait may form a critical part of a pattern in one situation, but have low pattern value in others. Teeth, for instance, have less diagnostic and classificatory significance in the lower vertebrates and invertebrates than in the mammals. The same holds in the field of culture; for instance as regards "dichotomized" social structure or moiety organization. In native Australia moieties are almost universal, and in New Guinea and Melanesia they are frequent. They basically determine marriage and descent; whom one may not marry, whom

one must marry. In Australia there is redichotomization into four sections, and even re-redichotomization into eight subsections. Related to this plan is the fact that all human beings with whom one has dealings are considered kin—are made into kin, if necessary—and put into one or the other moiety. This whole organization, often very elaborate, is superimposed on one of another type; the small local horde, autonomous and owning a territory, all its members interrelated through male descent, and therefore unable to marry horde members. The two plans of organization do not conflict but supplement each other. The moiety is international, as the native sees it, and therefore makes for successful amities and bonds outside, while not interfering with the subsistential and familial solidarity of the horde. This Australian scheme is very distinctive—infinitely varied in minor detail, but remarkably constant in underlying pattern.

Now moieties occur also in all other continents, but sporadically, by contrast. They occur often among peoples who are not living in hordes, and who do not insist on classifying everyone as a kinsman. Sometimes they are exogamous, occasionally endogamous, sometimes not connected with marriage or descent at all, but with ritual or games or government. All these other social dichotomizations in Asia, Africa and the Americas do not reduce to a consistent pattern; and their geographical distribution is tantalizingly spotty, instead of continuous. They are therefore justly regarded as having had a number of origins, separate in circumstances as well as in time and place, and with separate and different growths. Such similarities as they present, to one another and to Australian moieties, are therefore superficial and of the order of convergences.

There may well be in the nature of the human mind a deeply implanted tendency to construe and organize its world in terms of duality, bipolarity, and dichotomization, and this inclination may lie at the root of all moieties, in Australia and elsewhere. But even if there exists such a tendency, it is a psychological fact. It is only a condition of culture, not a phenomenon of it. On the cultural level, there remains the difference that in the Australian area the psychological trend toward dichotomization has been channeled into consistent, wide-spread, influential and probably ancient expression in a pattern of social structure, but elsewhere the same trend has entered only into local, intermittent, and secondary patterns.

These examples from the religious, intellectual, technological, economic and social fields may suffice to illustrate what is meant by fundamental patterns of culture. It is clear that they are something different from Benedict's "Patterns of Culture." These latter are psychological orientations of societies comparable to personality orientations or attitudes, such as paranoid, megalomanic, Apollonian, etc. When strongly developed, they are also influential, but selectively, and on the slant of a given culture, whereas the basic patterns here discussed operate constructively and often cross-culturally. In the Benedict approach, a pattern is a psychic constellation molding the typical personality of a society by imparting a certain warp to that society's culture. The basic patterns referred to in the present essay are the more pervasive and permanent forms assumed by cultural content, and tend to spread from one society and culture to others. In short, basic patterns are nexuses of culture traits which have assumed a definite and coherent structure, which function successfully, and which acquire major historic weight and persistence.

Returning to the biological analogy,

we must distinguish where the pattern parallel holds and where it does not hold. A particular culture is not comparable to a species, even though the members of any one society are given, by their common culture, a certain likeness of behavior somewhat comparable outwardly to the likeness of the members of one species. (The mechanisms which produce the likeness are of course quite different.) A culture is always, so far as we can judge, highly composite in the origin of its constituent materials. As I have said before, the branches of the tree of human culture are always growing together again. It is a commonplace that in our American civilization we speak a Germanic language shaped in England with the absorption of a larger Latin content, have a Palestinian religion, eat bread and meat of plants and animals probably first domesticated in or near Western Asia with additions from tropical America, drink coffee from Abyssinia and tea from China, write and read these words with letters originating in Phoenicia, added to in Greece, given their present shape in Rome, and first printed in Germany; and so on. There is no reason to believe that any living culture is less intricately hybrid. Therewith the analogy between cultures and species breaks down. Rather, it is ecological aggregates to which cultures can be compared: local associations of species of diverse origin. Certainly the larger faunal and floral regions, like the Palaearctic, Neotropical, Indo-Oriental, Ethiopian, Australo-Papuan, correspond strikingly, even in part to geographic coincidence, with the generally accepted major cultural regions; and there are parallels in retardation, specialization, and expansive productivity of new forms.

All this suggests that the nearest counterpart of the organic species in the field of culture is the culture trait and not the culture entity or culture. It is the species that is repetitive in its individuals; the trait that is repetitive in its exemplars—in the thousands of automobiles or stone axes manufactured according to one model or form, in the word or grammatical construction that is uttered over and over again. It is related species or genera or families or orders, that have persistent structural patterns in common; and it is among the traits that belong to one field of culture—such as writing, belief in deities, agriculture—that the persistent fundamental patterns of culture grow up. It would be easy to stretch the analogy too far; but within due limits it would seem to have utility in stimulating reflective inquiry, especially as regards the historical aspects of organic and super-organic phenomena.

THEY GAVE LIFE TO BONES

By CLAYTON HOAGLAND

EDITORIAL DEPARTMENT, *The Sun*, NEW YORK CITY

THERE lived in Philadelphia just a century ago a small boy whose interest in nature and science developed when he was very young. It was expressed in notes and drawings in his journal, and in little sketches he made to illustrate his letters with pictures of birds and reptiles. One day in 1846, when this boy was not yet seven, he was brought to a natural history museum that had been founded by Charles Willson Peale, soldier in the Revolutionary War and portrait painter. There the boy saw the mounted skeleton of an Eocene sea monster, the Zeuglodon. It is easy to imagine his awe as he beheld this exhibit, for it consisted of the bones of several skeletons strung together to the grotesque length of 114 feet!

Years later, when Edward Drinker Cope had become one of the foremost American paleontologists, the memory of this skeleton may well have amused him. As he had a lively imagination to the end of his days, the boyhood fancies aroused by sight of the monster he saw in the museum must have been wonderful indeed. Now, Cope's imagination was of the greatest value to paleontology. By using it he blew more than a breath of life into restorations of dinosaurs and other ancient creatures that were first arousing a great deal of public interest half a century ago. Before Cope died in 1897 he told a journalist friend, William H. Ballou, and the animal artist, Charles R. Knight, his conclusions as to the movements and habits of various Mesozoic animals over whose fossil remains he had spent years of exacting study.

We shall return to what Cope did for vertebrate paleontology, but it is well to recall here that his life spanned a period which began in the childhood of American fossil collecting, and which reached its peak in the early years of the twentieth century. By then a vast amount of knowledge had been organized, a number of amazing fossil skeletons had been found. It was by then possible for artists to model and to picture numerous extinct creatures realistically. By means of well-designed museum exhibits, and through books illustrated by Charles Knight, R. Bruce Horsfall, Erwin S. Christman and a few others, the public has learned to think of the great saurians, and other ancient reptiles and mammals, as *living* creatures, rather than as so many bones wired together and mounted on platforms, or in glass cases. The story of that difficult art is interwoven with the chronicle of fossil hunting in the United States for more than seventy-five years.[1]

What Cope, Joseph Leidy and O. C. Marsh did for paleontology was, as we know, pioneering, for these three established the science in America. Blundering efforts made in the years before they lived had advanced paleontology in this country only very slowly. Until well into the nineteenth century little was accomplished in finding and restoring fossil animals here. Few men seemed any more enlightened than in the days

[1] For valuable advice on collecting material for this article the author is grateful to Dr. George Pinkley, associate curator of comparative anatomy of the American Museum of Natural History; for information on Mr. Knight and Mr. Christman he acknowledges the help of Mr. Knight himself, of the late Dr. Walter Granger of the American Museum of Natural History, and of Erwin H. Christman, son of the artist. Mr. Horsfall and Mr. Allen were cooperative in providing information on their work.

when a discovery of the bones of a big vertebrate appeared to confirm the belief that human giants once lived on earth.

Among the most remarkable of all the early attempts to promote scientific interest in fossil creatures was that museum in Philadelphia visited by the boy Cope. He saw it fifty years after it had been established by Charles Willson Peale. When Peale had been a successful portrait painter for twenty years he installed in a large room in his house fossils he had collected, and various natural specimens he had received from friends. This collection was later moved to a hall in the building occupied by the Philosophical Society, and in 1802 moved to the State House, which had been vacated by the Legislature. The first board of directors of this museum, as formed in 1792, included Alexander Hamilton, James Madison and Robert Morris. One of the active members of the institution was George Washington.[2] It is important in our story, for there apparently it was that art and paleontology in America were first married.

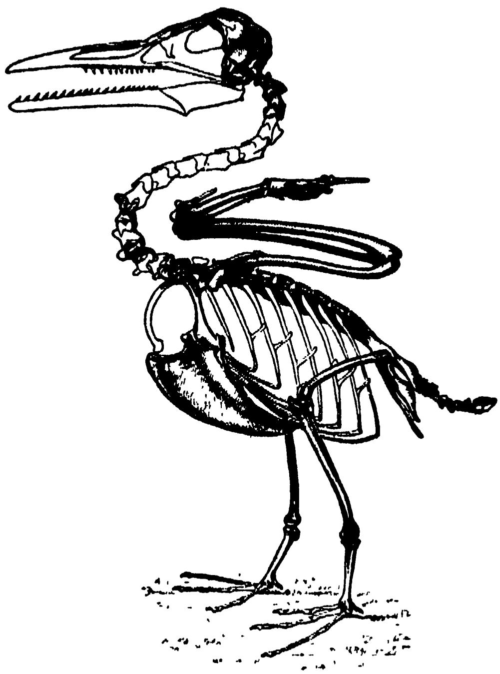
The elder Peale sensed to an extraordinary degree the need for public instruction in natural history. He was the first American artist who was successful in catching popular interest in authentic

[2] "Peale's Museum" by Harold Sellers Colton. *Popular Science*, September, 1909.

Municipal Museum, Baltimore

EXHUMATION OF THE MASTODON

A PAINTING BY CHARLES WILLSON PEALE DATED 1806, IN THE MRS. HARRY WHITE COLLECTION. THIS ARTIST, A SOLDIER AND SCIENTIST, EXCAVATED FROM PEAT BOGS NEAR NEWBURGH, NEW YORK, BONES FROM WHICH HE RECONSTRUCTED TWO SKELETONS. IN AN ACCOUNT OF THE FIND HIS SON REMBRANDT WROTE: "TWENTY-FIVE HANDS, AT HIGH WAGES, WERE ALMOST CONSTANTLY EMPLOYED AT WORK SO UNCOMFORTABLE AND SEVERE, THAT NOTHING BUT THEIR ANXIETY TO SEE THE HEAD, AND PARTICULARLY THE UNDER JAW, COULD HAVE KEPT UP THEIR RESOLUTION."



Peabody Museum

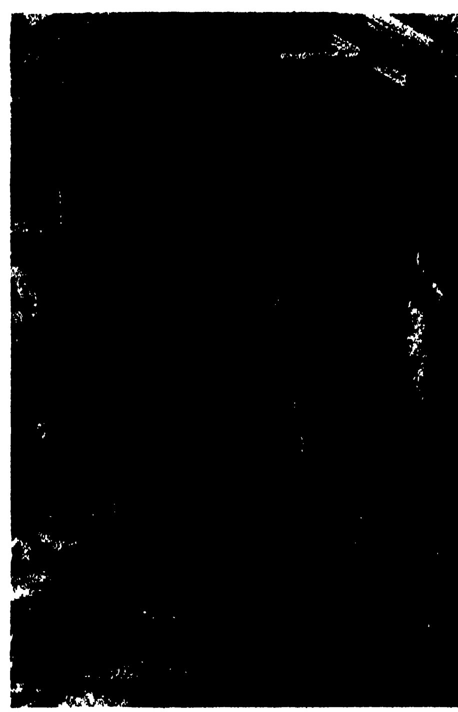
CRETACEOUS TOOTHED BIRD

A DRAWING BY FREDERICK BERGER, REPRESENTING ONE OF O. C. MARSH'S MOST FAMOUS RESTORATIONS, PUBLISHED IN THE EARLY 1880'S. THE BIRD STOOD LESS THAN A FOOT HIGH.

restorations of fossil animals. It seems likely he was among the first to think of exhibiting natural history specimens before correctly painted landscapes and in appropriate foregrounds. For the mounted quadrupeds in his museum he carved wooden skeletons, over which skin could be stretched—"a stupendous labor," he wrote, "originating from and affected by an enthusiastic desire of exhibiting a series of real forms as they exist in nature. . . ."

Peale went so far as to display paintings in the hall where he mounted the skeleton of a mastodon. This fossil he and his son Rembrandt had uncovered in 1801, at considerable cost, from marl pits near Newburgh, New York. Writing of the exhibit, Rembrandt Peale—erroneously describing it as the remains of a mammoth—told how two complete skeletons had been fashioned from the excavated bones of three animals. "Nothing is imaginary," he wrote, "and what we do not unquestionably know we leave deficient."

In the Municipal Museum of Baltimore is a painting by Peale, done in 1806, of the scene of the excavation for the mastodon bones. It depicts a huge pump drawing water from the pit, and among the throng on the brink stand Peale and his son, holding a large drawing of certain bones already uncovered. The elder Peale died in 1827. His museum survived another nineteen years; shortly after little Edward Cope's visit to it in 1846 the institution was closed for lack of support, and its collections were sold at auction.



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MODEL ROOM, CRYSTAL PALACE

IN THIS LONDON WORKSHOP IN THE EARLY 1850'S WATERHOUSE HAWKINS FASHIONED, LARGELY FROM IMAGINATION, MONSTROUS RESTORATIONS OF VARIOUS PREHISTORIC REPTILES IN "LIVING" ATTITUDES. THIS PICTURE APPEARED IN THE *Illustrated London News.*

About 1840, the year Cope was born, another Philadelphian, also destined to become an outstanding American scientist, entered the University of Pennsylvania. Joseph Leidy had studied art and had painted signs for a livelihood before he turned to medicine, anatomy and paleontology. His treatise "On the Fossil Horse of America" was published when he was but twenty-four. Osborn wrote of him:[3]

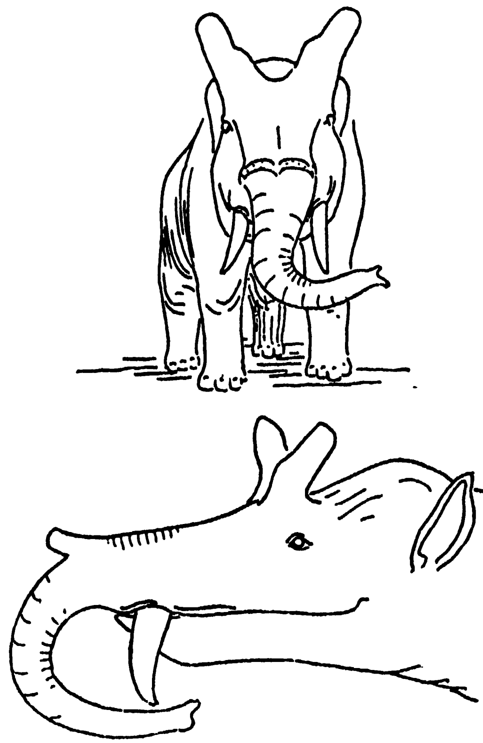
> Twelve years before Darwin brought forth the "Origin of Species" this young man was beginning to assemble a mass of data which would have been of value to the great British naturalist. As shown by Professor Scott, [William Berryman Scott] he was tracing the ancestral lineage of the horse, the camel, the rhinoceros, the tapir family, the titanotheres, and last, but not least, the anatomical forebears of man.

Peabody Museum

EARLY RESTORATIONS

A SKETCH OF A SMALL DINOSAUR AND OF WINGED AND MARINE REPTILES, PAINTED ABOUT SIXTY YEARS AGO BY ARTHUR LAKES, AMATEUR PALEONTOLOGIST AND ASSISTANT TO MARSH IN THE FIELD AND AT YALE UNIVERSITY. ("O. C. MARSH: PIONEER IN PALEONTOLOGY," C. SCHUCHERT AND C. M. LE VENE. YALE UNIVERSITY PRESS.)

[3] "Impressions of Great Naturalists," by Henry Fairfield Osborn, Scribner's, 1924.



COPE'S "DAWN EMPEROR"

A SKETCH FROM A LETTER BY EDWARD DRINKER COPE, DATED JANUARY 12, 1873, OF THE EOBASILEUS OF WYOMING, WHICH HE THEN DESCRIBED AS A PROBOSCIDEAN. OF THE UPPER SKETCH HE WROTE THAT THE CREATURE "WALKED WITH THE KNEE FAR BELOW THE BODY AS ELEPHANTS DO," AND THAT "THE HORNS AND HEAD ARE RATHER TOO LARGE." ("COPE: MASTER NATURALIST" BY HENRY FAIRFIELD OSBORN. PRINCETON UNIVERSITY PRESS.)

It was Dr. Leidy who described in exact detail the chelonian and mammalian fossils from Wisconsin, Iowa and Wyoming collected in the 1840's by Dr. Hiram Prout and David Owen. Leidy's research produced great blocks of those basic data on which the artists working for paleontology have devised realistic paintings and sculptures of prehistoric animals.

The science long remained a mystery to the public, however. In 1869 appeared Leidy's master work on the extinct mammalian fauna of North Dakota and Nebraska; yet not for another quarter of a century was any successful at-

tempt made to translate into truly life-like pictures and popular accounts the information compiled during the busy period of fossil hunting that began in Leidy's time.

In England, however, something was done, about 1854, that amused a few paleontologists while it probably enraged others. Waterhouse Hawkins, a sculptor, made models of several prehistoric creatures for an exhibit in the Crystal Palace in London. Authentic restorations were then scarce, for few complete skeletons had been found, so this sculptor let his imagination be carried away by images evoked by the names of the animals.[4] Working on a scale he believed to be life size, he depicted a Megalobatrachus as a giant frog, and modeled a Trachodon with a head like a huge iguana.

CRETACEOUS "HORNED LIZARD"
A PENCIL SKETCH BY COPE OF A PAIR-HORNED CERATOPSIAN IS INSCRIBED "THE HORNED LIZARD AGATHAUMUS SILVESTRIS (COPE) 25×15 FEET. FOREST AND JUNGLE." ("COPE: MASTER NATURALIST" BY HENRY FAIRFIELD OSBORN. PRINCETON UNIVERSITY PRESS.)

When O. C. Marsh, the paleontologist, saw these models in 1895 he wrote of them: "The dinosaurs seem . . . to have suffered much from both their enemies and their friends. Many of them were destroyed and dismembered long ago by their natural enemies, but, more recently, their friends have done them further injustice in putting together their scattered remains and restoring them to supposed life-like forms. . . . So far as I can judge, there is nothing like unto them in the heavens, or on the earth, or in the waters under the earth. . . ."[5]

Twenty years after Hawkins had modeled his monsters for London he was invited to do sculptures for the celebration in Philadelphia of the centenary of the Declaration of Independence. The secretary of the Smithsonian Institution sought Marsh's opinion of the project. That eminent scientist replied by letter in December, 1875, and this is what he wrote:

> I do not believe it possible at present to make restorations of any of the more important extinct animals of this country that will be of real value to science, or to the public. In a few cases where the material exists for a restoration of the skeleton alone, these materials have not yet been worked out with sufficient care to make such a restoration perfectly satisfactory, and to go beyond this would in my judgment almost certainly end in serious mistakes. Where the skeleton, etc., is only partially known the danger of error is of course much greater, and I think it would be very unwise to attempt restoration, as error in a case of this kind is very difficult to eradicate from the public mind, *e.g.*, the old restoration of Labyrinthodon (with frog-like body) still continues to appear in popular scientific books. . . . A few years hence we shall certainly have the material for some good restorations of our wonderful extinct animals, but the time is not yet.[6]

The prediction which closes this letter was fulfilled, as we know. But danger of error did not deter those in Philadelphia in 1875 who were sold on the Hawkins sculptures. That ambitious artist did finally make a plaster model of Cope's dinosaur Hadrosaurus for the Exposition. The secretary of the Smithsonian later was able to watch this dis-

[4] "Man and His Creations," by F. A. Lucas, *Natural History*, Vol. xxvi, May–June, 1926.

[5] "O. C. Marsh: Pioneer in Paleontology," by Charles Schuchert and Clara M. Le Vene; Yale University Press, 1940.

[6] *Op. cit.*, (Schuchert and Le Vene's "O. C. Marsh").

American Museum of Natural History

TRAPPED IN THE TAR POOLS

THE MURAL BY KNIGHT DEPICTS ACCURATELY THE STRUGGLES OF PREHISTORIC CREATURES CAUGHT IN THE RANCHO-LA-BREA PITCH POOLS OF LOS ANGELES, CALIFORNIA. A SABER-TOOTH TIGER HERE ATTACKS THREE GIANT GROUND SLOTHS (MEGATHERIUM). THE PAINTING ADORNS A WALL OF THE AMERICAN MUSEUM OF NATURAL HISTORY.

American Museum of Natural History

UINTATHERIUM BROUGHT TO LIFE

THIS PICTURE BY CHARLES R. KNIGHT PAINTED IN 1896 WAS ONE OF THE FIRST AUTHENTIC RECONSTRUCTIONS OF THIS EOCENE MAMMAL, WHOSE HABITS AND FORM WERE NOT THEN WELL-KNOWN. THE ARTIST USUALLY MADE SMALL WAX MODELS FROM ARTICULATED SKELETONS AND PLACED THEM IN SUNLIGHT TO OBTAIN THIRD-DIMENSION IN PAINTINGS.

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CRETACEOUS REPTILES OF THE SEA

A MOSASAUR SKELETON TWENTY NINE FEET LONG, FOUND IN KANSAS, WAS DESCRIBED BY OSBORN AND ILLUSTRATED BY KNIGHT IN *Science* IN DECEMBER, 1899. THIS MURAL SHOWING A MOSASAUR ATTACK ON ARCHELON (PTERANODONS FLYING ABOVE) WAS PAINTED THIRTY YEARS LATER.

integrate on its base outside the National Museum under the assaults of more than a decade of Washington weather.

Of course, the progress of fossil restoration has since shown the soundness of Marsh's opinion. His dourness, his suspicion of anything pseudo-scientific, was fitting in a temperament that earned for him at the Century Club the nickname of "the great dismal swamp." He was more than the head of the division of vertebrate paleontology of the U. S. Geological Survey—more than the distinguished professor of Yale; he became leader in the art of making lifelike restorations of the skeletal remains of toothed birds, swimming and flying reptiles and other extinct creatures of the earth. When the Peabody Museum in 1876 exhibited part of Marsh's collection of vertebrates, there was shown a papier-maché model of the dinoceras Mirabile, constructed from remains found in Wyoming.

It was about that time that the dinosaurs were attracting international attention. Many have doubtless heard of the long and bitter rivalry of Marsh and Cope. It lasted through a period when many fossil hunters were collecting in western United States; when Yale, Princeton and the American Museum of Natural History were receiving quantities of priceless material, later to be assembled and depicted, in full vitality, by artists who drew and modeled with scientific precision, under the critical eyes of paleontologists.

Most of the drawings of bones and skeletons that illustrated Marsh's publications were made by Frederick Berger, who served as artist at the Peabody Museum from 1875 until well into the 1890's. But perhaps the most talented of Marsh's assistants was Arthur Lakes. Here was an artist who also had field experience collecting bones in Colorado and other regions, as well as laboratory training at Yale, where for a time he helped string fossil remains into articulated skeletons. He was an English clergyman, engaged in the 1870's as teacher in Golden City, Colorado. There he made several notable discoveries of fossils, and not only produced scale drawings of bones as they were excavated, but worked in water color. He was among the first artists to make reliable restorations of prehistoric reptiles as they appeared in life.

It was Edward D. Cope, however, who was one of the first to study the bones of the dinosaurs that were unearthed in the West. His excavations in the marl pits of New Jersey in 1866 had attracted scientific attention. He had brought to

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GIANT GROUND SLOTH AND EARLY ARMADILLOS

IN "BEFORE THE DAWN OF HISTORY," KNIGHT DESCRIBED THE HUGE BUT HARMLESS MEGATHERIUM AS LIVING UNTIL COMPARATIVELY RECENT TIMES ON THE PLAINS OF SOUTH AMERICA. COMPARE THESE MURAL FIGURES WITH SKELETON SHOWN ON PAGE 130.

light remains of carnivorous dinosaurs, including the leaping monster, *Laelaps aquilunguis*. In 1873 he had made restorations of the Eobasileus, or Dawn Emperor of Wyoming, and three years later dug from Montana rock and soil the fossil skeleton of a giant flat-tailed Plesiosaur, *Elasmosaurus platyurus*, with its snaky neck. This reptile Knight depicted years later, hearing from Cope himself a description of the animal and an account of its submarine habits.

Cope's own restorations, in his sketches, now seem crude, but in the 1870's they were unique. Here was a great authority on prehistoric life, toiling day after day to assemble the bones of a dinosaur; then, after months of taxing labor, putting down his conception of the creature as it probably was in life. It was in a letter of January, 1873, that he made one of his first sketches of the Wyoming "Dawn Emperor," then classified as a probiscidean. He marked the sketch, "The horns and head are rather too large. . . ." Another important restoration, done about 1878, was Cope's drawing on brown wrapping paper of an amphibious lizard, the inscription giving its length as 75 feet—the *Camarasaurus supremus* (Cope). Later restorations corrected the shortness of the legs.

Not till 1897, however, did Cope meet Knight, and soon after was assured that this skilled artist could translate into terrifyingly real forms the conceptions developed in decades of scientific study. To his wife in March, 1897, Cope wrote:

> Professor Osborn was here yesterday and spent a good deal of the afternoon, and we had a pleasant talk. He is going to call on the New York surgeon who attends my case and learn what he can. Mr. Knight, the artist for the Century Magazine, has been here a couple of days, and is getting figures of Naosaurus, Laelaps, Elasmosaurus, Agathaumus, Camarasaurus, and other saurians. He is very original in attitudes.[7]

Three weeks later Cope died. Marsh lived but two years longer. Leidy had passed on in 1891. But the work of all three had laid a vast foundation for the art that was to make fossils live.

Osborn, in his "Impressions of Great Naturalists," made an enlightening reference to Cope's labors, which preceded by many years some of Knight's restorations:

> As a pioneer in exploration among these giant animals he was obliged to draw his conclusions largely from fragmentary and imperfect materials, leaving the field open to Professor Marsh's more exhaustive explorations, which were supported by the government. Yet Professor Cope illuminated the incomplete fragments with his reasoning and his fertile imagination. When a

[7] "Cope: Master Naturalist," by Henry Fairfield Osborn, Princeton University Press.

American Museum of Natural History

AMERICAN MASTODON SCULPTURED BY KNIGHT

FORTY YEARS AGO THE AMERICAN MUSEUM OF NATURAL HISTORY, UNDER OSBORN'S DIRECTION, SOLD CASTS AND MODELS MADE FROM RESTORATIONS IN WAX OF FOSSIL VERTEBRATES, SEVERAL OF WHICH COPE HAD DESCRIBED TO KNIGHT.

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ARMORED JURASSIC MONSTER

THIS RESTORATION OF THE DINOSAUR STEGOSAURUS, WHICH IS IN A MURAL DONE FOR THE FIELD MUSEUM OF NATURAL HISTORY BY CHARLES R. KNIGHT, IS ONE OF A SERIES OF TWENTY-EIGHT LARGE PAINTINGS WHICH REQUIRED FIVE YEARS FOR COMPLETION.

bone came into his hands, his first step was to turn it over and over, to comprehend its form thoroughly, and to compare it with its nearest ally, then to throw out a conjecture as to its uses and its relation to the life economy of the animal. . . . His conclusions as to the habits and modes of locomotion of these animals, often so grotesque as to excite laughter, were suggestive revivals from the vast deeps of time of the muscular and nervous life which once impelled the mighty bones. It is fortunate that some of this imaginative history has been written down by Mr. Ballou and that, although physically enfeebled by a mortal illness, Professor Cope in his last days was able to convey to Mr. Knight, the artist, his impressions of how these ancient saurians lived and moved.

Years elapsed, as we know, between the excavation of fossil bones and the begun to set up in the museum exhibits of fossil animals in life-like poses. While in New York in 1896 Professor Schuchert of Yale saw the skeleton of a brontothere mounted by Adam Hermann in accordance with Osborn's ideas. When the method was proposed to G. Browne Goode, then director of the National Museum in Washington, however, Schuchert was informed, in somewhat contemptuous tones, that he had not seen fine paleontology in New York, but fine art.[8] In Washington, as in many other museums, the collections of skeletons of fossil vertebrates were left on the shelves for the exclusive sight of paleontologists

SCULPTURES OF THE FOUR-TOED HORSE

THESE GRACEFUL MODELS OF EOHIPPUS, A LOWER EOCENE CREATURE ONLY A FOOT HIGH AT THE SHOULDER, WERE MADE BY CHARLES R. KNIGHT FOR THE AMERICAN MUSEUM OF NATURAL HISTORY.

restorations in realistic form by painters and sculptors working from skeletons. Yet it was this, finally, which helped to arouse wide public interest in prehistoric animals. How, to that end, the American Museum of Natural History created more dramatic exhibits is a story too long to tell here. Some of it may be briefly indicated, as the employment of artists was part of an organized effort to inform the public of advances in natural history. Thrust upon art suddenly were greater opportunities than were ever before possible to interpret the science of paleontology for the lay public.

Early in the 1890's Dr. Osborn had —until the movement promoted by Osborn spread.

Many technical books, as well as works of popular science published in the early 1900's, however, were more excitingly illustrated than any that had been published in the previous two decades. When Cope's "Batrachia and Reptilia (Extinct) of North America" was published in 1869, it was illustrated almost entirely with drawings of bones, the main plates being done by Edwin Sheppard. This was not a book for the public, it was true; yet even serious students of

[8] "O C. Marsh: Pioneer in Paleontology," by Schuchert and Le Vene, Yale University Press.

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PROCESSION OF WOOLLY MAMMOTHS

KNIGHT PAINTED PICTURES AND MADE MODELS OF LIVING ELEPHANTS AS WELL AS STUDIES OF PREHISTORIC SKELETONS, AND EXAMINED LE MOUSTIER CAVE DRAWINGS AT LES EYZIES, FRANCE, DONE BY CRO-MAGNON ARTISTS.

science could welcome such a work as Frederick A. Lucas's "Animals before Man in North America—Their Lives and Times," published in 1902 by Appleton. The frontpiece reproduced a painting of the Great Horned Dinosaur by Knight, and there were realistic drawings of giant crustaceans, titanotheres and mas-

GIANT WOLVES AND SABER–TOOTHED TIGER

FIGHTING OVER THE CARCASS OF A MAMMOTH IN A PLEISTOCENE TAR POOL IN SOUTHERN CALIFORNIA: A RESTORATION ON CANVAS BY ROBERT BRUCE HORSFALL. ("LAND MAMMALS IN THE WESTERN HEMISPHERE" BY WILLIAM BERRYMAN SCOTT. MACMILLAN COMPANY.)

todons by Gleeson, Knight and others. These restorations were in addition, of course, to photographs and diagrams of skeletons and parts of the creatures discussed. Osborn's "The Age of Mammals in Europe, Asia and North America," issued in 1910, included a preface in which the author explained:

> The reader who finds it difficult to picture the rare and ancient forms of mammals has to thank that gifted artist of the life of the extinct world, Mr. Charles R. Knight, for the series of restorations drawn under my personal direction, which are brought together for the first time in this volume. It is always to be understood that such restorations represent hypotheses merely, or approximations to the truth.

This volume was also illustrated by several fine drawings by Erwin S. Christman, of whom we shall tell later.

It was in 1891 that Osborn opened his department of mammalian paleontology at the American Museum of Natural History. His relations with Cope and Marsh had begun as early as 1877, during Osborn's student days at Princeton, when he and William Berryman Scott went fossil hunting in Colorado. For fifteen years, in field work, teaching and laboratory research, he had been accumulating experience for the opportunity that enabled him to present dramatically the story of what science had learned of the great ancient reptiles, and of the forebears of the horse, the rhinoceros and the elephant. His influence on the educational policies of natural history museums in this country is still to be excelled.

COMBAT OVER MERYCOIDODON

HORSFALL HERE DEPICTS "FALSE" SABER-TOOTH TIGER, OR NIMRAVIS, AND TRUE SABER-TOOTH, OR EUSMILUS. PAINTED FOR SCOTT'S "LAND MAMMALS IN THE WESTERN HEMISPHERE."

Before Cope died the American Museum bought his collection. Osborn sent William Diller Matthew to Philadelphia in 1895 to catalogue and pack the mass of fossil material. In the next few years Matthew was able to exercise "a keen interest in the problems that were constantly being raised in the attempts to

mount fossil skeletons in lifelike poses."[9] These problems "were to be solved only by carefully correlated studies on the postures and skeletons of living animals." The work went forward for a while under Osborn's brilliant first assistant, Dr. Jacob L. Wortman. These restorations of the bones of extinct animals provided the sculptors and painters at the museum with abundant material for models and pictures that were vividly realistic, as well as accurate. In turn, the artists helped the museum to design better exhibits.

Before this art was fully developed there were certain important ventures in illustrated journalism, to arouse interest and inform the public with authoritative accounts of what was recently discovered about the reptiles and mammals of the earth's remote past. The achievements of paleontologists in this country had at last become ripe for popular consumption. What Marsh had said in 1875 was no longer true: It was now possible to present good restorations of most of the important extinct animals of the United States.

Marsh himself was long opposed to mounting fossil specimens from his collection for public display. At the end of 1895 he published on a large sheet a dozen illustrations of skeletons of dinosaurs, but this was by no means a gesture toward popular science. Some of the monthly magazines took up the subject, devoting many pages to lively articles, and to illustrations that then seemed sensational, but that were scientifically made. In a few years there was an amazing increase in popular interest in prehistoric creatures.

In the *Century Magazine* for September, 1896, was an article by Osborn

[9] William K. Gregory in *Natural History*, November–December, 1930.

American Museum of Natural History

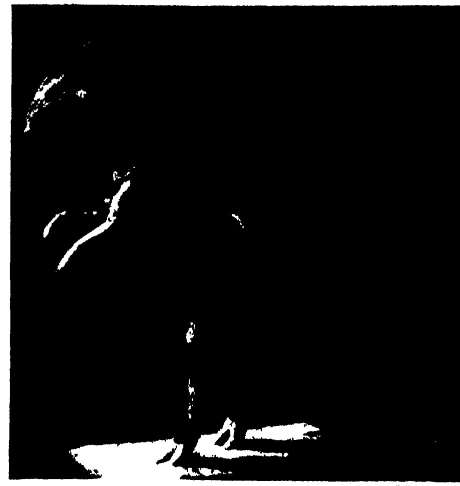
THE OLIGOCENE BRONTOPS AND EOTITANOPS

LIFE-SIZE HEADS OF TITANOTHERES WERE INSTALLED IN THE AMERICAN MUSEUM OF NATURAL HISTORY IN 1912, MANY MODELS OF WHICH WERE PREPARED BY PROFESSOR WILLIAM K. GREGORY AND ERWIN S. CHRISTMAN. THE LATTER, A GIFTED YOUNG ARTIST, WORKED FOR TWENTY YEARS ON THE RESTORATIONS FOR THE MUSEUM.

entitled "Prehistoric Quadrupeds of the Rockies." The author described the ancient animals in detail. Effectively he dramatized the life and habits of the great four-toed Uintathere of the Bridger region of southern Wyoming and Utah; the Mesonyx, largest of the carnivores; the four-toed horse of Wasatch Lake in the Big Horn Mountains of Wyoming; the Titanotheres of the South Dakota Lake Basin; the Metamynodon, or aquatic rhino, and other creatures until then unheard of by most readers of the *Century*.

In this article it was made clear that every one of the animals illustrated had been restored in skeleton form after many years of hard work, both in the field and in the workshops of Yale, Princeton and the American Museum of Natural History. Osborn included a lively description of fossil hunting. The article was illustrated with reproductions of nine paintings by Charles R. Knight.

Soon after Cope died in 1897 the *Century* carried another article by Osborn on the great naturalist, with illustrations by Knight of leaping dinosaurs and fin-backed lizards. In the same issue was William Hosea Ballou's article, "Strange Creatures of the Past," also illustrated by Knight with six paintings. Here was described Cope's method of examining the skeletons of saurians of the Triassic, Jurassic and Cretaceous eras, Ballou explaining: "During several months preceding his [Cope's] death his original and interesting views upon these animals, and his ingenious speculations regarding their habits, were imparted to the writer." Another of Ballou's articles appeared in the June, 1898, *Popular Science Monthly*. Entitled "The Serpentlike Sea Saurians," it was illustrated with a full-page drawing by J. Carter Beard, as well as with pen drawings by Cope, Marsh and Williston. The Beard illustration was



American Museum of Natural History

PARASAUROLOPHUS WALKERI

A MODEL BY LOUISE GERMANN MADE IN 1937 FROM STUDIES OF A TYPE SKELETON IN THE UNIVERSITY OF TORONTO.

crude and unrealistic in showing "the Great Cretaceous Ocean" filled with very animated Mosasaurs, marine turtles, bulldog fish and a Plesiosaur, from restorations by Williston and Case. Ballou wrote sensationally of the Mososaurs, in a style later used for Sunday supplement articles that may have caused nightmares among readers of Mr. Hearst's New York *American*.

When the Hall of Natural History was formally opened at Trinity College in Hartford, Conn., at the end of 1900, Dr. Osborn delivered there a popular lecture on the recent progress of vertebrate paleontology in America. He declared, "The true modern spirit in which to study a fossil vertebrate is to imagine it as living, moving, walking, swimming or flying, begetting its kind. . . ." He went on to say that it was possible to study a fossil as "thinking,"—as fearing its enemies and devising means of escape—for the organs of sight and smell had been studied as part of "fossil psychology." He explained that one of the great advances of recent work consisted "in the fact that we have secured com-

plete skeletons in the place of fragmentary parts."[10]

That statement of forty years ago, with its emphasis on the psychology of animals, may serve to reveal to present-day readers one secret of the effectiveness of the art then first employed to interpret paleontology to the people. This art was believable as well as exciting, for fossil material had been amassed in quantities. Besides, scientists made new restorations whenever new knowledge radically modified their first conceptions. It was in this spirit that the American Museum of Natural History, from the time of Osborn's efforts to attract public attention to the discoveries of paleontologists, employed Knight, Horsfall, Christman and several other artists.

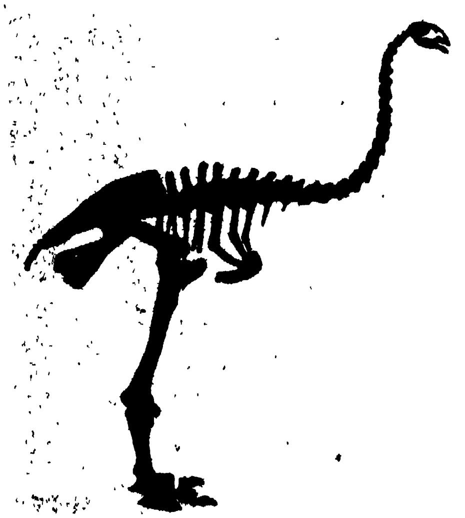
Knight began by sketching live animals as a hobby. He studied animal anatomy in the taxidermist shop of the museum while he was working as a designer for J. and R. Lamb of New York, makers of stained glass. He was born in Brooklyn in 1874, attended Brooklyn Polytechnic Institute, and studied at the Art Students League. In his book, "Before the Dawn of History,"[11] he mentions the incident that opened for him the career he has followed for forty-eight years. One day in 1894 Dr. Jacob Wortman of the American Museum asked Knight to make a small water color of the Elotherium. From various complete skeletons and skulls the artist made a restoration that was satisfactory. He believes that his principal equipment for such work from the beginning was his "intense love of and interest in the forms and attitudes of living animals." He has frequently said that no artist can put life into drawings and paintings of extinct animals unless he knows something of the life, attitudes and psychology of living creatures.

Working under the supervision of Osborn, Wortman, Matthew and others at the museum, Knight helped devise a

[10] *Science*, January 11, 1901.

[11] Whittlesey House, 1935.

MODEL OF BRONTOSAURUS—A JURASSIC DINOSAUR
CONSTRUCTED BY JAMES E. ALLEN AT THE AMERICAN MUSEUM OF NATURAL HISTORY.



SKELETON OF EMEUS CRASSUS
IN THE COLLECTION OF FIELD MUSEUM OF NATURAL HISTORY.

EMEUS CRASSUS RESTORATION
THE SKELETON AT THE LEFT PROVIDED THE BASIC FORM FOR THE PAINTING BY J. C. HANSEN.

method of making pictorial reconstructions from the inside out. In three or four years his application to this work produced remarkable results. He had illustrated books and magazine stories in the early 1890's, but from the time he began drawing and painting for paleontology he developed an acute sense of the vitality of the ancient creatures he depicted. It was his primary purpose to impart life to his restorations, so that fossil mammals and reptiles would become almost as familiar as modern horses and dogs to all who saw his models or pictures.

In the spring of 1898 the museum issued a catalogue of casts, models and photographs of restorations of fossil vertebrates. Reviewing this in *Science*, Osborn referred to "the difficulty of arousing interest and spreading accurate information among a very large class of inquisitive but wholly uninformed people." To overcome this difficulty members of the Department of Vertebrate Paleontology of the museum had made special studies of methods of holding the interest of visitors to the museum. One result was the exhibition with fossils of the series of water colors by Knight. Several of the creatures illustrated in the catalogue of casts were those whose movements were described to Knight by Cope. Among these was, of course, the leaping dinosaur. Knight's model was based on the fragmentary skeleton in the Cope collection, and on restorations by Marsh of the allied form, Ceratosaurus.

It was the artist's practice to make first a number of models in wax in accordance with the proportions and muscular indications of the skeleton. From evidence at hand he was able to draw conclusions about the feeding habits of the animal, and its attitudes, as shown by the positions of the joints and the angles of feet and limbs. Then, to get the solidity of three dimensions on paper, and to reproduce shadows of the animals on the ground, the models were placed in sunlight, and the paintings made from them. It was when Osborn decided the wax models themselves were worth preserving that casts were made and a catalogue issued. Colleges, scien-

tific schools and individual students could thus obtain material for study. The original sculptures and paintings were a gift to the museum from J. Pierpont Morgan.

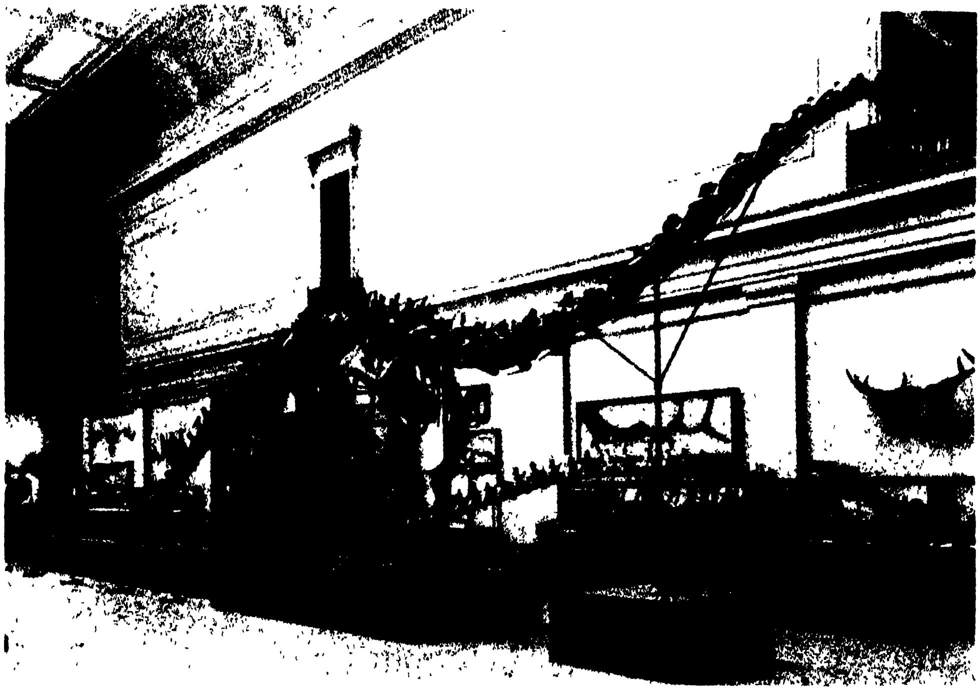
By early summer of 1898 Knight had made about twenty water colors and a number of models, and had begun others. The artist's realistic poses of ancient animals had considerable influence on the designing of displays for the museum. Skeletons of many specimens were mounted after his models. The artist made a notable series of models of primitive elephants, and in the early years of this century a series of restorations of Pleistocene and Miocene horses. Probably Knight has become most widely known for his murals in the American Museum of Natural History, and in the Field Museum in Chicago. His first large wall decoration was begun in the New York museum in the Hall of the Age of Man. For the next ten years he was engaged in painting the series of wall panels which have impressed all who have sought in pictures a clearer idea of life on earth as it must have appeared in the main phases of its evolution. Knight then did twenty-eight large panels for the Field Museum, between 1926 and 1930, and returned to decorate the Hall of the Age of Mammals in the American Museum.

One of the latter panels shows mammals of the Upper Pliocene period: the short-jawed Stegomastodon, the Glyptotherium, an armadillo-like animal, and the one-toed horse Plesippus, also the early camel, or Pliauchenia. Another panel, completed in 1934, when Knight observed the fortieth anniversary of his

© *Field Museum of Natural History*

THE SKELETON OF A GIANT SLOTH

A GOOD SPECIMEN OF MEGATHERIUM WHICH DISCLOSES SOME OF THE EVIDENCE ON WHICH KNIGHT MADE HIS ANATOMICAL STUDIES FOR THE MURAL SHOWN ON PAGE 121.



SKELETON OF A DINOSAUR, SEVENTY-TWO FEET IN LENGTH
THIS RESTORATION OF DIPLODOCUS LONGUS MARSH IN THE UNITED STATES NATIONAL MUSEUM WAS SHIPPED PIECEMEAL TO THE CAPITOL FROM THE DINOSAUR NATIONAL MONUMENT IN UTAH.

association with the museum, illustrates mammals of the Oligocene period in a restoration of a typical scene in Nebraska and South Dakota. In the Museum of Natural History in Los Angeles is a fifty-foot panel of the Rancho-La-Brea pitch pools. The mural in the Planetarium in New York, by the way, is also by Knight; it illustrates the story of the Moon Goddess in the mythology of the Plains Indian. In 1940 Knight made his first lithographs, a series of fourteen, illustrating invertebrate and vertebrate creatures through the ages. His paintings have been reproduced in countless books and magazine articles on prehistoric life.

Another talented artist who came to the American Museum of Natural History before 1900 was R. Bruce Horsfall. He recalls that it was Osborn's quest for a pen and ink draughtsman that first brought him commissions in 1898. Horsfall, whose studio is now in Washington, has had a distinguished career as artist, author and naturalist. Born in Iowa in 1869, he studied in Cincinnati Art Academy and in Munich and Paris, and exhibited in the Chicago Exposition of 1893. In addition to his work for the New York museum, which chiefly consisted in drawings of fossil skeletons, he did restorations of extinct animals for *McClure's Magazine.* Professor William Berryman Scott employed him to illustrate the fossils of Patagonia, on which he spent some eight years. He made illustrations for Scott's "A History of Land Mammals in the Western Hemisphere," first published in 1913, and also painted backgrounds for museum displays.

A gifted lad of 15 came to the American Museum of Natural History one day

in 1900. He was encouraged to copy skulls and make other studies of anatomy, and to play about with pencils and modeling clay. This boy had an extraordinary interest in animal life and was able to express that interest in art. His name was Erwin S. Christman, and he spent more than twenty years of his short life as an artist for paleontology. In particular he developed an ability as sculptor, and became a valuable member of the museum's staff before he was much older than the average college freshman. He studied at the Art Students League and the American Academy of Design. He obtained some of his earliest practice in the difficult branch of art he had chosen by making wash drawings of the teeth of Titanotheres.

Then Christman turned to pen and ink, and modeling clay, and made a series of drawings of the skeletons of dinosaurs. One of his notable achievements was the restoration of the dinosaur Camarasaurus. From innumerable drawings of the bones, and after years of painstaking work, he made cut-outs and arranged these in a realistic pose. This he used as the basic design for what has been considered one of the best sculptured models of a dinosaur ever made.[12]

Osborn's "The Age of Mammals in Europe, Asia and North America" included several photographs of Christman's models of primitive Proboscideans and other mammals. In April, 1912, the museum installed an exhibit of a series of life-size heads of the Titanotheres, those gigantic horned monsters that once roamed the plains of the Dakotas and were distant relatives of the rhinoceros. These, displayed in the Hall of Vertebrate Paleontology, were modeled by Christman under the direction of Osborn and Gregory. A few years later Gregory and Christman, after arduous research,

[12] "Erwin S. Christman—Draughtsman, Artist, Sculptor," by William K. Gregory, *Natural History*, November–December, 1921.

United States National Museum

ARMORED DINOSAUR IN THE UNITED STATES NATIONAL MUSEUM

THE LIFE-SIZE RESTORATION OF STEGOSAURUS WAS MADE FOR THE ST. LOUIS EXPOSITION OF 1904. THE MUSEUM HAS A SKELETON SHOWING ARRANGEMENT OF THE DERMAL PLATES.

succeeded in devising a complete restoration of a Titanothere which, for the first time, presented the musculature of those creatures. Christman died in 1921 at the age of thirty-six, after more than twenty-one years' service to science and education. In a fine tribute Dr. Gregory wrote of him that "his work was characterized not only by creative vision but by fidelity of detail," and praised him as an intelligent and sympathetic assistant to the scientific staff.[13]

Among the artists who have worked for the museum in more recent years have been John C. Germann and Louise Waller Germann; E. Rungius Fulda, whose painting of a Miocene camel bed-ground was done under direction of Dr. Barnum Brown; and M. Flinsch, who made a number of drawings of elephants and mastodons. Charles J. Lang made a reconstruction of the Longirostine Mastodont.

The art director of the agency in charge of advertising for Sinclair Oil Company saw in *Collier's Weekly* about ten years ago an illustration of a Jurassic sea monster. He commissioned the artist, James E. Allen, to do a series of dinosaurs for advertising illustrations. Few readers who saw them knew how much careful work went into these. Allen made numerous studies at the American Museum of Natural History under the supervision of Dr. Barnum Brown, with guidance from Dr. Walter Granger, Dr. Robert C. Murphy, Dr. Gregory and others. A handicap under which he worked was, of course, the speed with which commercial illustration is required. His dinosaurs were later reproduced in booklets and on stamps that were printed in some 5,000,000 copies, to supply requests from a public that responded with intense interest to this example of art in the service of science.

[13] *Natural History*, November–December, 1921.

At the Field Museum in Chicago many restorations of fossil vertebrates have been made by John Conrad Hansen. His crayon and pencil drawings and pen and ink studies of prehistoric animals have been used by the museum to illustrate cased exhibits of the articulated skeletons. Born in Trondhjem, Norway, seventy-three years ago, he came to this country as a boy and lived in Minneapolis. There for nearly forty years he worked as a lithographer, specializing in vignette engraving for the Monarch Lithographic Company. He opened a commercial studio in Chicago in 1929, and joined the staff of the Field Museum about four years ago. Since early youth he has painted portraits, landscapes and figure studies in oil.

The art that has interpreted the life work of America's paleontologists, as we have seen, has been more than technical illustration—it has often been fine art. It has required an extraordinary combination of talents, for its best practitioners not only have had the full equipment of professional artists—they have adapted their technique to illustration, which was made dramatic to attract interest. They have approached their subject with more than ordinary understanding of animal anatomy. They have worked, for the most part, with material which required a happy blend of imagination and scientific precision; material on which they must exercise skill and patience under the eyes of scientists who would not approve work in which imagination had run away with fact. These have been the rigid requirements of a branch of art which has, in most instances, brought little recognition to the artist, but which has made a major contribution to education—to the more effective use of museums as educational institutions.

SOIL AND WATER ECONOMY IN THE PUEBLO SOUTHWEST

II. Evaluation of Primitive Methods of Conservation

By Dr. GUY R. STEWART and Dr. MAURICE DONNELLY

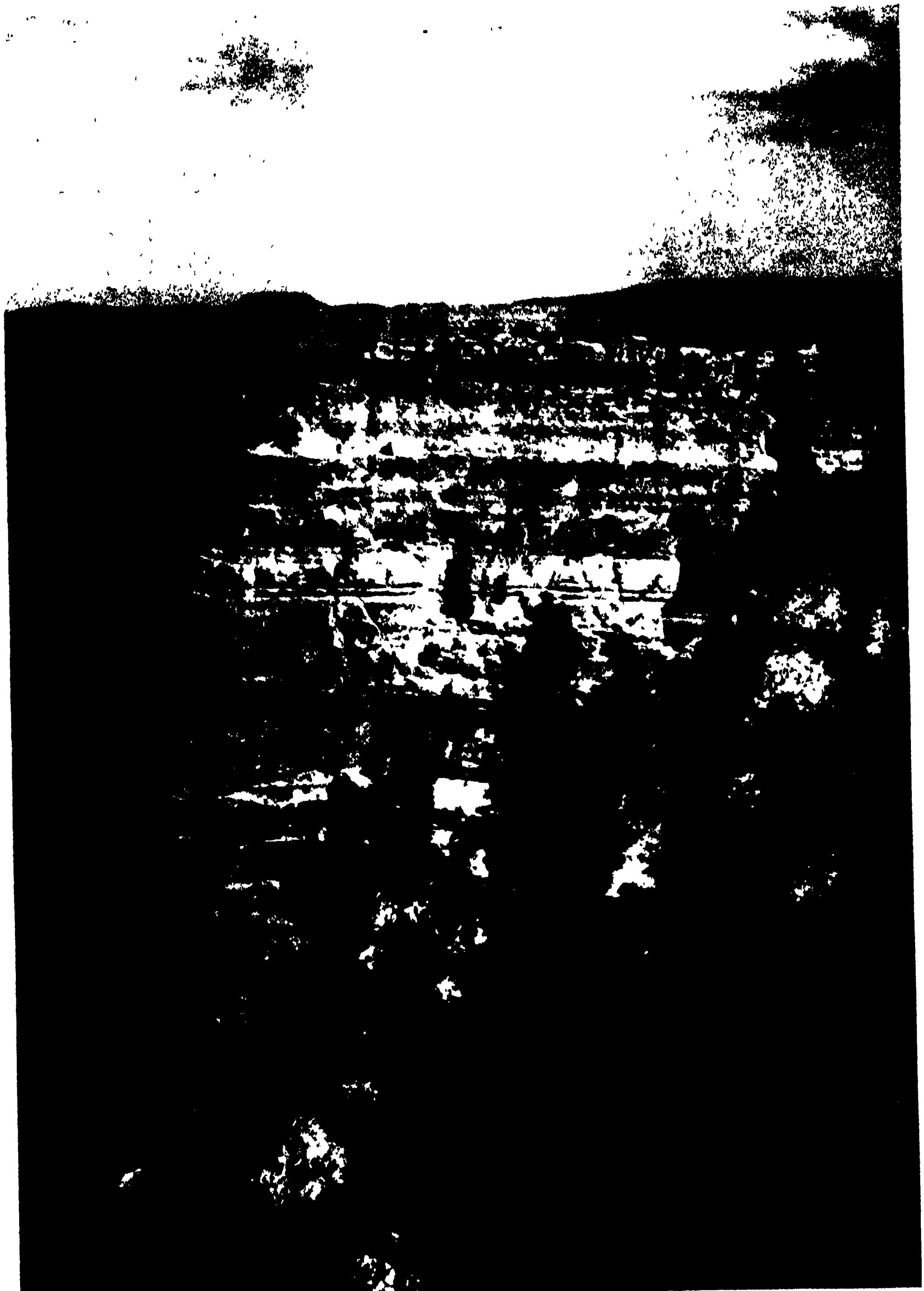
SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

In the work carried out so far, we have found five principal types of conservation practice which were used by the early Pueblo farmers. The first of these consisted of boulder bench terraces which received local run-off from adjacent slopes, and so supplemented the rainfall by adding the precipitation from tracts several times as large as that on which the crop was planted. Many such plots were tiny in size, even 8 by 10 feet in area, but in most cases consisted of a series of two or three boulder checks which would have helped to retain run-off coming onto small gardens 75 to 100 feet long by 20 to 30 feet wide. The large terraced site on the Walhalla Plateau is an example of field scale water conservation upon this type of area, where local run-off was arrested. Very few terraces of this sort were on level land, and even with gradients no steeper than 2½ to 3 per cent. there has been a gradual loss of surface soil. In their simplest form boulder bench terraces merely reduced the velocity of flow of run-off water, thereby increasing the water intake into the soil. It is probable that this type of moisture- and soil-saving dam was first constructed after some early cultivator observed that water was retarded and soil retained by fallen tree trunks which lay across small drainage depressions. Where rocks supported and reinforced the tree branches or trunks it was found that the structure was likely to be more permanent. The natural occurrence of simple wood and rock water-arresting checks has often been observed by us at Mesa Verde and at other points in the Pueblo country, and such demonstrations could not have failed to attract the attention of a primitive cultivator.

The effectiveness of the ancient boulder and rock bench terraces depended on the steepness of the slope on which the structure was placed and on the care with which the boulder or rock wall was constructed. On slopes of 6 to 8 per cent. there was little retention of soil, but on gentle slopes, under 3 to 4 per cent., terraces of this class have effectively held soils of stable structure until the wall was broached by floods.

The use of land receiving local run-off in present-day Pueblo agriculture can be seen in the bean fields adjacent to the Hopi mesas or the corn fields at Nutria on the Zuni reservation, which are supplied with additional water from surrounding hill slopes.

A second group of conservation installations which can still be identified, both in the northern and southern portions of the Pueblo country, were the village check dam plots, placed in the upper part of any convenient watercourse where the grade was not too steep and the stream flow relatively gentle. In most cases, other than at Mesa Verde, these check dam gardens were on a slope of 4 to 6 per cent., so that the resulting plot had a moderate grade of 1½ to 3 per cent. When first installed these plots were probably effective devices to conserve soil and water as the soil was of moderate depth and surplus water filled the root zone after each rainfall which produced run-off. There was, however, some washing away of the sloping surface soil so the greater part of



ANGELS WINDOW, NORTH RIM, GRAND CANYON, NEAR WALHALLA PLATEAU.

these installations could not be classed as a method of stabilizing a permanent system of agriculture. At Mesa Verde, this type of garden plot had the best development which we have discovered so far. A definite type of construction can be recognized, with the ends of the checks carefully tied in to the sides of the stream channel and the dam itself built up to a sufficient height so that a level plot resulted. The portions of these plots which now remain at the sides of the streams indicate that excellent small gardens were formed, with an adequate depth of soil for corn, beans or squash. While the dams were kept in repair the Mesa Verde type of garden check may be classed as a splendid installation well designed to conserve soil and utilize storm run-off for crop production.

A third type of conservation practice was the use of flood water distributing ditches to bring flash stream flow or surface run-off onto corn land or garden patches. This conservation measure had its greatest development in the widespread ditch system of the Salt River Valley, which one of us[1] has discussed previously. These ditches are often described as a system of irrigating ditches. From all the evidence of the general use of impounded flood water for crop production in the Southwest, it appears probable that the Salt River Valley system was a well-organized method of distributing and spreading flood flow.

The Mesa Verde flood water ditch is the only instance we have discovered so far of this method of handling water in the northern Pueblo country. The ditch trapped a large flow of run-off, both from the uplands and from ground immediately adjacent to it. Along the ditch there are remains of small field checks and recognizable areas of probable diversion onto corn land. These accessory methods of slowing up run-off, impounded soil and increased the penetration of water, thereby retaining a greater supply of moisture for plant growth.

BOULDER TERRACES OF SMALL ROCK

UPPER PART OF A LARGE TERRACED SITE ON THE WALHALLA PLATEAU, GRAND CANYON.

The wide, relatively flat channel of this ditch suggests that it may have been planted to corn in the same manner that natural flood waterways in modern Hopi or Zuni corn fields are still treated.

A fourth method of conservation of water was the use of springs or small, live streams for the irrigation of village garden plots. The Tohalena Gardens, near Navajo Mountain, were an example of a garden area, which was supplied with water, partly by run-off from the hills to the northeast and partly by flow from a live spring. The rainfall and spring flow were conserved by throwing up banks to surround the plots which were frequently built up on step-like terraces. Gardens of this type, which have been cultivated intensively by the Hopis since early days, can be seen at Hotevilla and Wipo Springs, and on a smaller scale wherever continuous flow of water was available adjacent to the Hopi villages.

The fifth and most important practice consisted in cropping the flood water fields where the principal corn crops of the villages were produced. By the use of temporary brush and soil dams, occasionally reinforced with rock, water from flash floods was diverted from its normal channel across adjacent fields where it could be impounded and absorbed into the soil. Strangely enough, even though these tracts were the largest areas of the crop land that was planted, they are often the most difficult primitive sites to recognize at the present day. This is because a relatively small amount of rock was used in the water-spreading dams which deflected the water across the corn land.

A typical flood plain field was almost level with a slight fall of about 1 per cent. so that it was easy to distribute the water over the entire area. Cushing[12] was one of the first to make detailed

[12] Frank H. Cushing, "Zuni Breadstuff," New York Museum of the American Indian, Heye Foundation, 1920.

VIEW OF THE NORTH RIM OF THE GRAND CANYON
NEAR ONE OF THE VILLAGE SITES ON THE WALHALLA PLATEAU.

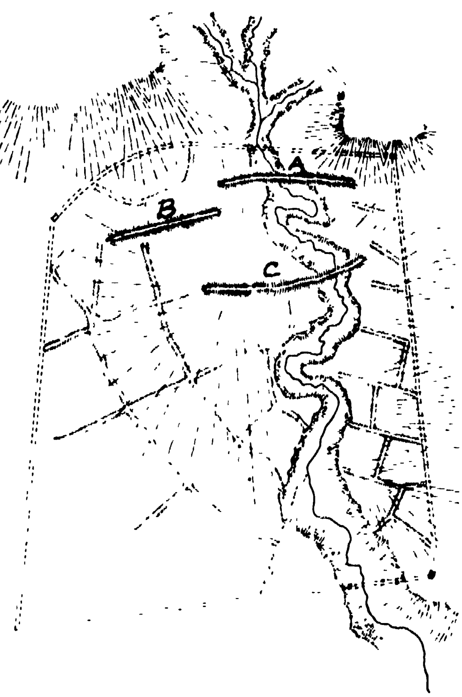


FIG. 4. PLAN OF ZUNI CORNFIELD IN 1884. AFTER CUSHING.

studies of flood water irrigation by Pueblo methods. In his residence at Zuni as a member of the tribe from 1880–85 he interested himself in all the agricultural operations, as well as in the ceremonial life of the tribe. The manner in which a Zuni cultivator handled the flood water flow on a field in 1884 is shown in Fig. 4. A dam of earth and brush was placed across the stream at the top of the field at A. This deflected the water over to the secondary spreader B, and as the water swept round B, the earth dikes were cut through and then closed to retain impounded water. An additional dam at C again kept the water from flowing down the main channel and helped to turn it over the balance of the field. Cushing notes that it was frequently possible to reclaim a sandy flood plain for agricultural use by turning silty flows out over the sandy land for a season or two until the water-holding capacity of the sandy soil had been improved.

Essentially the same process of flood irrigation can be seen on many of the Zuni fields now in use and a careful study was made of the methods followed on all the Zuni corn land during the season of 1940, through the cooperation of Melvin Helander, Zuni agent for the Indian Service. The manner of handling the corn land was discussed with a number of the older Zuni, who were all agreed that the practice of flood irrigation traced back to their ancestors. The principal change which has occurred recently has been the introduction of plowing, which is now causing modifications in the early planting technique described by one of us[1] previously. One of the larger fields examined in 1940 had a series of four dams across the stream channel to spread the flood water over the field. The secondary effect of the dams was to keep the stream bed on the same level as the field and prevent the development of gullies. By this method of treatment the stream channel did not always stay in one place, so the entire field, including the stream, was planted in its entirety. A heavy flood flow might alter the course of the main channel and wash out a strip of corn, but the loss was no greater than if the strip of land along the main stream bed had been left free from a crop. Planting corn in the stream also has aided in reducing the turbulence of the flood flow and was one of the few instances where we have seen the corn plant used as an accessory vegetative aid in the control of small flood flows.

The discussions with Zuni cultivators brought out several of the risks to which flood-water farming is subject. At times an excessive amount of sand may be deposited in, and adjacent to, the stream channel so that a part of the land will not retain water sufficiently to carry the crop through periods of drouth. The

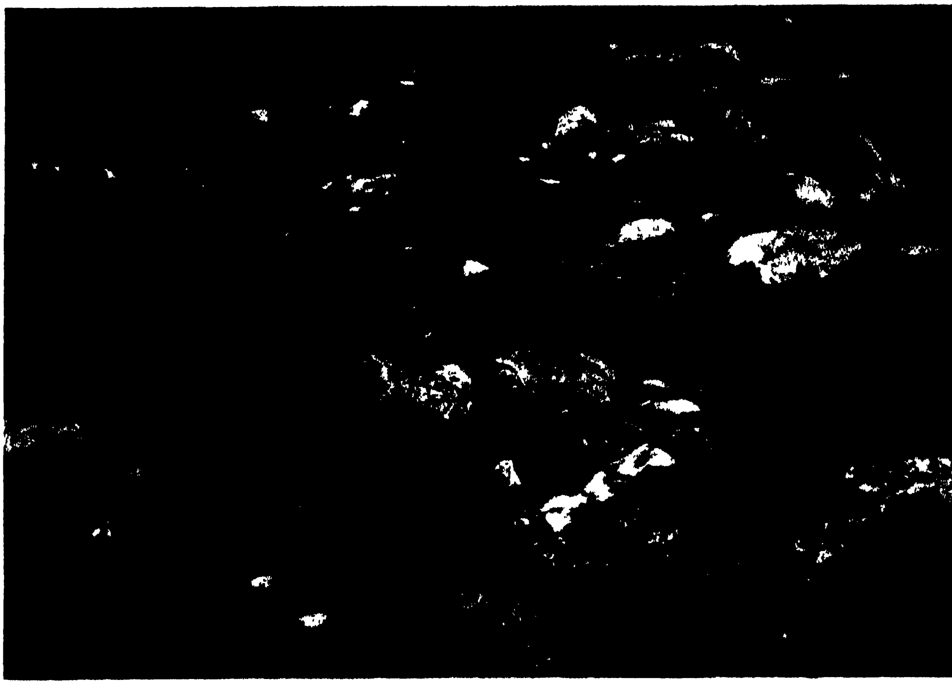
Zuni informants claimed, however, that this condition may be corrected by later flows in the season, but sometimes continues until more silt is deposited in the following year. An exceptionally heavy flood flow occasionally washes out portions of the planted crop, but the philosophic comment was made that the rest of the field would probably yield enough to make up for this loss, because of the extra supply of water received. The only thing which they felt permanently injured a flood-water field was deep trenching or gullying of the stream channel, which would make it impossible to turn water out on the land. Such gullying must be checked by preventive dams as soon as it began. Reagan[13] has indicated his belief in the importance of the filling in of valley flood-water fields in the Pueblo country as a preventive of serious erosion and gullying.

[13] Albert B. Reagan, "Stream Aggradation through Irrigation," *Pan-Am. Geologist*, Vol. 42, No. 5, pp. 335–344, 1924.

The fact that the evidences of the early use of land for flood-water fields is now often difficult to detect makes us urge that archeologists working in the Southwest devote more attention to reporting such information. Certainly a solution of the manner in which the primitive peoples of the Pueblo country lived and adapted themselves to their environment should be of interest to all scientists working in this portion of the country, and warrants a united attack by both agriculturists and archeologists. In the case of some sites, as of Chaco Canyon, the very location of the corn fields which would have supported the large communities residing there has been a matter of question. Several reports quoted by Hodge[14] have suggested that one or more primitive ditches were used to take water from the canyon and irrigate fields at

[14] F. W. Hodge, "Handbook of the American Indians North of Mexico." *Bull.* 30, Bureau Amer. Ethnology, Parts 1 and 2, Washington, 1907–1910. Section on Irrigation, p. 620.

STREAM CHECK DAM, BELOW RAINBOW LODGE, NAVAJO MOUNTAIN.



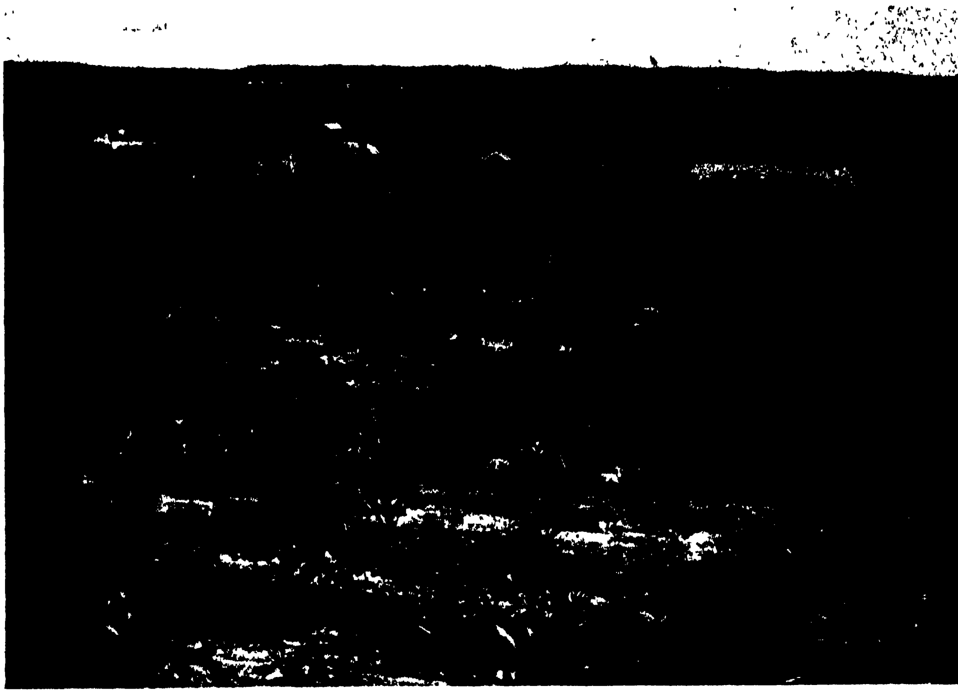
PRIMITIVE BOULDER FIELD CHECK AT TOHALENA GARDENS
ABOUT TWO MILES FROM NAVAJO MOUNTAIN.

some distance from the main villages. There has been some difference of opinion, however, whether these ditches described may not have been constructed by the Navajo during the early period of their residence in the country.

Through the cooperation of the Soil Conservation Service Office at Albuquerque, an examination of the entire area adjacent to Chaco Canyon was made from the air. No signs of a large system of diversion ditches, which would have watered corn land sufficient for the Chaco villages, could be detected. On the other hand, the aerial study of Chaco Canyon and the adjacent Escabada Wash suggested that these two streams had adequate areas of land suitable for flood-water corn fields in the canyon beds, themselves. The main gully running down Chaco Canyon has every appearance of being a channel cut in recent years. Were this channel not present, the stream flow could be spread in many places to form an excellent system of corn fields. When Simpson[15] passed through Chaco Canyon in 1849 he described conditions there in some detail and stated that the stream near his camp not far from Pueblo Wejiji had a width of 8 feet and a depth of 1½ feet and that occasional patches of excellent grama grass were located along the canyon. There was no mention of the deeply trenched gully that the stream now occupies, which apparently had not been cut out at the time of Simpson's visit.

The country surrounding Chaco Canyon is as heavily grazed as the areas we have examined adjacent to Navajo Mountain. It, therefore, seems probable that the rapidity of run-off has increased in modern times with consequent trench-

[15] James H. Simpson, "Report of an Expedition into the Navajo Country in 1849." In reports of the Secretary of War, Senate Ex. Doc. No. 64, 31st Cong., 1st Sess.



ZUNI CORN FIELD AND FARMSTEAD AT NUTRIA
CORN LAND RECEIVES RUN-OFF FROM ADJACENT HILLS.

ing of fields which could originally have been used as flood-water corn land. Even had there been no increase in the rate of run-off, the observations made at Zuni show that catastrophic gullying of corn land can occur in flood-water fields when diversion dams no longer stabilize the channel. Hence, disuse alone might have started the formation of a deep arroyo. It appears probable that reduction in vegetative cover after the time of Simpson's visit has intensified run-off and contributed to the destructive process.

All the ancient conservation installations that we have examined have undergone moderate to severe soil erosion. The period when this erosion took place is difficult to determine at the present day. If soil washing was occurring during the time of early settlement it might account for part of the shift in the prehistoric population. The Pueblo people had no livestock to reduce vegetative cover over a wide extent of surrounding country. They did have an appreciable need for firewood and timber for support of the upper floors of the houses. It is difficult to estimate whether wood and brush cutting would have been so complete that erosion might have been accelerated on the sloping village fields. Our examination of one large terraced site on the North Rim of the Grand Canyon indicated that erosion might have occurred at an early date. This is not the case for the region as a whole.

There is, in fact, considerable evidence that vegetative cover on at least part of the Pueblo country has decreased within historic times with a consequent increase in the susceptibility of appreciable areas to sheet erosion. This is shown in a series of reports of official expeditions made across portions of the Pueblo country in the period of 1846–1857. Lieu-

tenant Colonel Emory[16] accompanied the first United States military expedition into New Mexico in 1846. After the occupation of Sante Fe, Emory was a member of the army which proceeded down the lower Rio Grande, and then turned across the mountains until the Gila was reached and followed to the Colorado. At a number of places in his journal he described the typical vegetation on the lower Rio Grande, which included large patches of grama grass. Later, while crossing the table land enroute to the Gila, he commented on the great abundance of the winter grama grass. Occasional notes were made by Simpson[17] of the supply of grass for teams and stock in his report of the survey of the wagon route from Fort Smith, Arkansas, to Santa Fe, New Mexico, in 1849. Sitgreaves[18] made a journey from Zuni to the Colorado River in 1852, crossing the country below the San Francisco Mountains. In his report he mentioned the excellent grass cover found on the hills away from the stream. Whipple,[19] on his railway survey near the 35th parallel of latitude, crossed the Pueblo country in 1853 approximately along the route of the present Sante Fe Railroad and commented on the thick carpet of grama grass that covered the western hills.

[16] Lt. Col. W. H. Emory, "Notes of a Military Reconnaissance from Fort Leavenworth in Missouri to San Diego, California." (Made in 1846–7 with the advanced guard of the Army of the West). Thirtieth Cong., First Sess., Ex. Doc. No. 41, Feb. 9, 1848, pp. 1–614.

[17] James H. Simpson, U. S. Engineer Dept. Report from the Secretary of War Communicating the report and map of the route from Fort Smith, Arkansas to Santa Fe, N. M., Washington, 1850. U. S. 31st Cong., 1st Sess., Senate Ex. doc. No. 12, 25 pages, 4 maps.

[18] L. Sitgreaves, Report on an Expedition down the Zuni and Colorado Rivers, Senate, 32nd Cong., 2nd Sess., Ex. Doc. No. 59, pp. 1–190, with plates, Washington, 1853.

[19] Lt. A. W. Whipple, "Report of Explorations for a Railway Route near the Thirty-fifth Parallel of Latitude from the Mississippi River to the Pacific Ocean." 33rd Cong., 1st Sess., Ex. Doc. No. 129, pp. 1–154, 1854.

The most detailed report of vegetative growth, however, is that made by Beale[20] covering his survey of the wagon road from Fort Defiance to the Colorado River in 1857. As this route was intended for the use of emigrants to California he made detailed notes on the supply of grass and water for stock and wood for cooking. He summarized his observations as follows: "You will find by my journal that we encamped sometimes without wood and sometimes without water, but never without abundant grass." Recently Lockett[21] has followed the Beale Trail through the Navajo country and has shown photographically the great change which has occurred in loss of vegetative cover and resulting soil erosion at Beale's camp sites, except at a few locations where grazing has been controlled.

Probably the most eroded sites examined by us were those located on the slopes of Navajo Mountain, where the grazing by sheep in late years has been heavy. In addition, the soils at the mountain foot are largely sandy or gravelly in texture, showing poor resistance to erosion.

The land at Mesa Verde was grazed only moderately by cattle prior to 1906, and is now protected by better vegetative cover than is found around Navajo Mountain. The soils on most portions of Mesa Verde visited by us are loams or silt loams, which appear to be less erodible than the looser soils of the Navajo Mountain area so that a good portion of the surface horizons are still in place on the mesa.

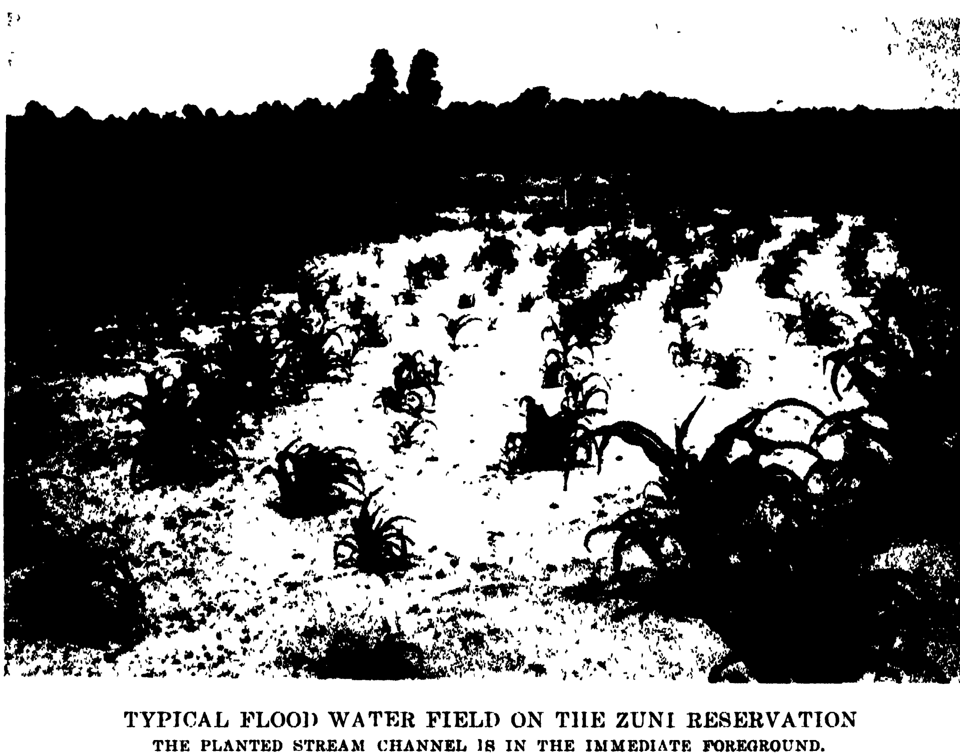
In a careful review, Bryan[22] examined the records of early travelers and explorers in the Southwest in an endeavor

[20] E. F. Beale, "Wagon Road from Fort Defiance to the Colorado River." House of Representatives. Executive Doc. No. 124, 35th Cong., 1st Sess., Washington, 1858, pp. 1–87.

[21] H. C. Lockett, "Along the Beale Trail," Education Div., Office Indian Affairs, U. S. Dept. of Interior, 1939, pp. 1–56.

[22] Kirk Bryan, *Science*, 62: 338–344, 1925.

RUINS OF HAWIKUH, SOUTH OF ZUNI
THIS IS THE SITE WHERE CORONADO FIRST MET THE PUEBLO PEOPLE.



TYPICAL FLOOD WATER FIELD ON THE ZUNI RESERVATION
THE PLANTED STREAM CHANNEL IS IN THE IMMEDIATE FOREGROUND.

VIEW OF PUEBLO BONITO AND CHACO CANYON FROM THE AIR
SHOWING THE DEEP STREAM GULLY WHICH HAS APPARENTLY DEVELOPED IN HISTORIC TIMES.

to date the cutting of arroyos in the Southwest. He concluded that active cutting of most of these arroyos (channels) was initiated within the last one hundred years. The present period of arroyo cutting in the semi-arid Southwest coincides, then, with the period of decline in the density of vegetation. Along with other evidence, Bryan's conclusion gives support to our belief that a considerable part of the sheet erosion on ancient agricultural sites, now abandoned, has taken place in comparatively recent time.

CONCLUSIONS

(1) The conservation practices examined at four early centers of Pueblo culture had excellent value as water conserving devices. Essentially the same methods have carried over into present day Pueblo agriculture and are in successful use.

(2) Boulder bench terraces on sloping land, probably never gave effective control of soil erosion, but may have had some value on areas where vegetative cover was sufficient to reduce the velocity of run-off water. Check dam bench terraces built so that a level plot of soil was formed, were excellent soil conserving structures so long as they were repaired and maintained. The flood water irrigation fields, on which the major portion of the early corn crops were raised, had an important place in conserving soil and when handled by the Pueblo methods of water diversion, effectually prevented gullying.

(3) The primitive conservation practices of the early Pueblo farmers demanded constant vigilance to maintain them in use and showed that the agricultural economy of this region was delicately adjusted to the needs of the early communities.

SIRENS AND BELS

By Dr. J. O. PERRINE

ASSISTANT VICE PRESIDENT, AMERICAN TELEPHONE AND TELEGRAPH COMPANY

THE present war is a technical war. Never before have the scientist and the expert been called upon in such large numbers to apply their wide array of techniques to the purpose of war. However many new phases there are in this war compared to previous wars, one outstanding difference is the airplane. As a result of the airplane and bombings and air attacks on military and civilian areas, the production of a shrieking, howling and roaring siren signal became another problem that could be attacked and solved with technical knowledge.

ACOUSTIC ENVIRONMENT

In days gone by our environment was largely visual. Since the last war we have been living in a new environment, an acoustic environment. From radio loud speakers and public address systems in home, theater, stadium and school, words and music are pelted at us. We have all become sound-conscious as never before.

To be sure, sound is a commonplace phenomenon and likewise a simple phenomenon. However, from the engineering point of view sound seemed to have defied measurement technique. Engineers, of course, seek to measure, to calibrate, to quantitatively evaluate. But sound waves, intangible and invisible and fragile and impotent as stuff for an engineer to work with, did not readily submit to quantitative analysis. Even electricity lent itself to measurement more readily than did sound.

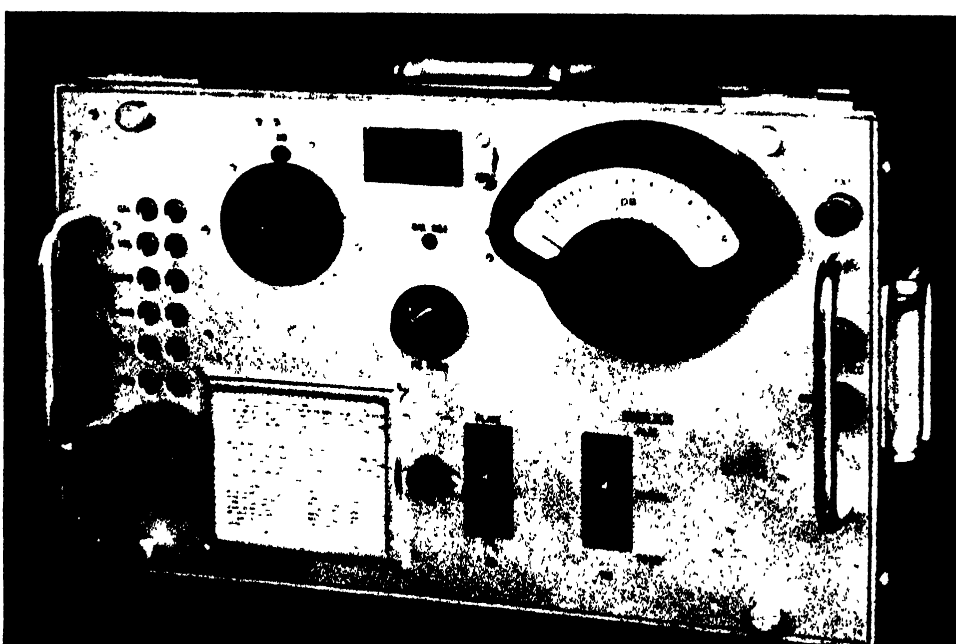


FIG. 1. ELECTRICAL METER FOR MEASURING INTENSITY OF SOUND

MEASUREMENTS ARE CALIBRATED IN DECIBELS. A MICROPHONE IS CONNECTED EXTERNALLY.

(*Courtesy of PM*)

FIG. 2. THE CHRYSLER-BELL VICTORY SIREN
WHICH PRODUCES THE LOUDEST CONTINUOUS NOISE EVER CREATED BY MECHANICAL MEANS.

Sound and Electricity

Happily, during the last quarter century sound has submitted to engineering technique via the development of electrical communication. Sound became measurable when translated to electrical currents. These fine techniques, contributing of course in times of peace in splendid fashion to the interrelations of speech, music, radio and telephony, were very promptly applied to the problem of making a sound, just sound—noise, if you will—a very loud sound. This is where the siren comes in. In an airplane attack, the pantosonic roar of a siren became the best means of warning the countryside. Sound is the Paul Revere of 1942. It travels swiftly, 770 miles per hour, and can now be made loud enough to be heard adequately at a distance comparable to that from Old North Church to "the rude bridge that arched the flood" at Concord.

Sound Is Power

It has already been suggested that, in engineering circles, sound was an obstreperous sort of phenomenon. To measure the frequency of vibration of sounds was not difficult, but to measure the sheer power, the horse-power or the kilowatts of sounds was very difficult. The relations of power and steam, compressed air, coal, light, electric motors and generators, men, horses, the sun, tides, waterfalls, were well understood. They were sizable, tangible, interrelated and readily intervalued. Watts, kilowatts, horsepower, were terms readily associated with the above forms of power. But to measure sound waves in terms of watts and horse-power eluded the grasp of the instruments of the physicist and the engineer. One knew sounds were manifestations of power, but just how much power was a question not so easy to answer as in the field of horses and tractors and

boilers and hydraulic dams. To find the loudness of sounds apart from the human ear, to compare sounds objectively, was not a straightforward task. Lord Rayleigh developed the so-called Rayleigh disc for this purpose, but it was a fickle and whimsical piece of apparatus. Primarily, of course, the difficulty centered around the fact that the power, the watts, the horse-power or any other name equally horrendous and technical to the layman, was so small, so tiny, so microscopic, or rather micro-acoustic and even micro-micro-acoustic.

Horse-power and Kilowatts

A horse can, by a system of pulleys, lift a weight of 625 pounds, vertically upwards at the rate of six miles per hour. Such performance in 1775 was the basis of determining and establishing the magnitude of a horse-power by testing the horses drawing the wagons of the Nottingham, England, Brewery. That power was something one could understand; it was sizable, it was something to see, to sense, to appreciate. A 4,000-HP locomotive supplying power to pull a passenger train speeding through the night at 60 miles an hour must provide at all times a force of 25,000 lbs. A 1,000-HP motor can drive an airplane through the clouds at a speed of 200 miles per hour. All the time the propellers and their wind blasts have to push or pull with a force of 1,950 pounds. But a sound wave, intangible, invisible and evanescent, what is its power, its horse-power (perhaps "butterfly" or "aspen leaf power" would be a better term)? What is its thrust, its impinging force, its pressure?

So to make super-sirens in a war in 1942, one needed to know a lot of technique about loudness of sounds, rather to know about the power of sounds. Likewise one needed to know a great deal about the sensitivity, the acuity of the human ear. A great array of acoustic techniques have been accumulating during the last quarter century. Aristotle, Pythagoras and Galileo blazed trails long ago. Saveur, Helmholtz, Rayleigh, Barton, Miller, Webster, Crandall and Sabine continued to blaze trails. To-day the trails are widened and deepened. They have been blasted by the zealous research of another Sabine, of Knudsen, Stewart, Wegel, Watson, Frederick, Dudley, Wente, Steinberg, Lane and Fletcher.

To exert power, as engineers use the term, is to do something at a certain speed. The unit is the horse-power. A strong and powerful horse was found capable, as previously mentioned, of pulling with a force of 625 pounds at the rate of a brisk walk, six miles per hour. Just as surveyors measure distance in miles, rods and feet, so engineers measure power in horse-power and watts and kilowatts. A kilowatt is a thousand watts and a kilowatt is 1.34 horse-power. One watt is .00134 horse-power. In school days the 5,280 and 16½ used to make bothersome problems in arithmetic. The 1.34 number sometimes does the same in the arithmetic of engineering.

Mouth and Ears

The most common sound is speech. How much power in human speech? The sound waves coming out of one's mouth, talking in an average way, embody power; they are carrying an effect, the capability of affecting the human eardrum. They bear power. It is a surprisingly small parcel of power; it is .000,000134 horse-power, or .00001 watt. This is quite below comprehension as a discrete amount of power. To say that the combined power of ordinary speech from the mouths of 5,000,000 people is equivalent to the power of a 50-watt incandescent light might give a vague notion as to how small it is. The finest technique of the alliance of electricity and sound was necessary to determine this value. In passing it is of particular interest to mention again that the mea-

surement of sound intensity has been accomplished via the route of electrical measurement. Microphones, amplifiers and thermophones have been the general instrumentalities.

If one shouts, the power of the sound is increased 100 times, namely, .001 watt or .0000134 horse-power. A mighty basso singing a mighty fortissimo may, for a short time, radiate a note of one watt (.00134 HP). A loud speaker at the stadium may be radiating a speech to 50,000 people, but the power of the sound is small, perhaps 10 watts (.13 HP).

The human ear is a sensitive and an acute sound detector. But just how tiny, how micro-micro-acoustic a sound can the ear hear? Again that was not an easy value to find, and of course varies with age and with people and with pitch of sound. On the average, however, modern technique has determined the value as .000,000,000,000,0001 watt (decimal point 15 ciphers one watt), *i.e.*, .000,000,000,000,000001 horse-power (decimal point 17 ciphers one horse-power). This value of sound intensity then becomes the value of the audible threshold of the human ear. It can be established as a sort of bench mark, a sort of sea level of sound intensity. Pike's Peak is 14,110 feet above sea level. So sounds in their intensity are nowadays compared to that minimum intensity which human ears can, on the average, hear, as the sea level of audition. In fact the term "level" is a good one. Sounds can be talked about very appropriately in their intensities as being at such and such a level. The zero level, the arbitrary comparison level, is that minimum sound intensity which the human ear can just hear.

Range of Speech and Hearing Intensities

Human beings can whisper and give out one ten-thousandth as much power (.000,000,00001 horse-power) and they can shout 100 times as loud as average speech (.00001 horse-power), a ratio of one million (1,000,000). That is, human beings can speak in sounds varying 1,000,000-fold in power.

In the realm of hearing, if sounds bear power of .001 watt (.000,001 HP), the ear is hurt by such a relatively large amount. This value of sound intensity might be called the threshold of pain. But it is in the range of sounds which a human ear can hear that it is such a remarkable device. Sounds varying ten million-million fold are sensed by the human ear without discomfort. The ten million-million fold is the ratio of .001 watt which produces pain to the .000,000,000,000,0001 watt which the ear can just hear. Great orchestras play fortissimos and pianissimos. These vary 20,000,000-fold in horse-power or watts. The aggregate power of their majestic music is but 75 watts, the power of a medium-sized incandescent electric light. The mouth and the ear are acoustic systems of our human bodies. They are both small power systems, as compared to walking, jumping and running. Yet the small amount of power in the normal speaking voice is, after all, many, many times more intense than is necessary for reception by the human ear. If the power embodied in the words of ordinary conversation could be parceled out in tiny bits just intense enough for a human ear to register, 100,000,000,000 could be made to hear. This is of course about 25 times more people than there are on the earth. An ordinary postage stamp is not a very ponderous object. If one had the time and inclination to cut a stamp into 50,000 bits and these bits could be dropped on the eardrum from about an inch above at the rate of 1,000 pieces a second, the ear would hear this lilliputian machine gun rat-a-tat-tat.

Sound Intensity Measurement

The subject of this homily is "Sirens and Bels." The reader quickly glancing at the title probably thought the printer had made a mistake, that it should be "Sirens and Bells" or perhaps even "Sirens and Belles." No, the word is

"bels" because the bel is the term (named, to be sure, in honor of Alexander Graham Bell) by which acoustical engineers measure the relative sound intensity of sirens, music and speech.

Mountain Levels and Sound Levels

The super-siren developed by the Bell Telephone Laboratories and designed and built by the Chrysler Corporation has elicited much interest lately. This discussion has been presented to help prepare the mind of the lay reader and the non-physicist not only to understand a bit about the Chrysler-Bell siren but also to appreciate the enormity of the sound it emits.

Mountains to be called mountains perhaps have to be at least 1,000 feet above sea level. But as mountains go, they do not vary a great deal relatively. Some Alleghany mountains are 4,000 feet and Mt. Katahdin in Maine is 5,200 feet. Mount Washington in New Hampshire is 6,300 feet. Among the Rockies there are some peaks 14,000 feet above sea level. Mt. McKinley is 20,000 feet and Everest 29,150 feet. So the highest mountain is only 29 times higher than the lowest mountain. Twenty-nine (29) is not a big number to say, and it is not a great number in numerical magnitude. The heights of mountains do not vary many fold, and therefore large numbers are not required to compare their altitudes.

But the levels of sounds which the ear can hear vary many, many-fold among themselves in the first place, and are individually a great many-fold greater compared to the audible threshold in the second place. Human ears can hear sounds varying in intensity ten million-million-fold. A shout is 1,000,000 times as intense as a whisper. A great orchestra radiates music rising and falling 20,000,000-fold. A thunderclap is heard by 50,000,000 people. Whenever sounds are talked about and compared, the numbers get awfully big. So the sound engineers (unlike the astronomers) not wanting to use such big numbers and scare themselves and perhaps the public, too, therefore said, after considerable deliberation: We won't use actual numerical values when we compare intensity of sound to the minimum level of ears, namely, .000,000,000,000,0001 watt—watts per square centimeter, to be completely explicit. We will do a bit of maneuvering and take a short cut. Instead of using the actual number we will use the number of decimal places in the number, if the number is less than 1, or the number of ciphers if the number is greater than 1. The number of decimal places and the number of ciphers will always be the same. One one-hundredth (.01) has two decimal places and one hundred (100) has two ciphers. So a watt of sound intensity would be an enormous number of times greater than the audible threshold detectable by the ear, .000,000,000,000,0001 watt. This number has 16 decimal places. One watt of sound would be 10,000,000,000,000,000 times as great. This number has 16 ciphers.

Ratios and Super-Ratios and Bels

Engineers, particularly acoustic and communication engineers, must have a general heritage of Scotch ancestry. So in this case to conserve words, breath and pencil, they discuss matters with their colleagues in terse fashion by agreeing that, instead of a lot of decimal places and a lot of ciphers, they will merely give the number of the decimal places or the number of ciphers and call them "bels." In the case cited they would say 16 bels. In the case of man shouting 100 times as loud as normal speech they would say 2 bels. If one sound intensity is 1,000,000 times as great as another he would say 6 bels. Such a procedure is very sensible as well as Scotch. It shortens conversation and it expedites exchange of ideas. In no wise does it inject a difficult-to-understand idea into the picture.

Sound intensity and other things, too, for that matter, are said to vary so many bels. "Other things" might be intensity

of radio signals, electric current and the relative distances of planets and stars. These vary a great many-fold, hence the use of the term "bel" would be appropriate. The variation of wages, speed of trains, heights of mountains and many other items in the welter of everyday life is generally small, so old-fashioned percentage is sufficient to talk about them.

Furthermore, if one has a lot of sounds whose power is expressed in bels above the level of the threshold, their comparison among the individual sound intensities is readily and simply arrived at. One siren has a sound whose intensity is 14 bels, a second 12 bels. Then the first is merely 2 bels louder. Now of course 2 bels greater means 2 ciphers, so if one wants to know more about the sounds, the first is 100-fold more intense than the first. But the engineer says that 100 is too big a number to think about. He suggests 2 bels. He has only subtracted 12 from 14 to get 2, which in turn means 2 ciphers, which means 100.

Bels and Decibels

One other point by way of exposition and then the sound intensity of the Bell-Chrysler siren will be readily understood. The engineer for various reasons decided the bel was even too great a unit, since 10-fold is 1 bel. Sounds which varied as much as a bel, namely, one cipher, was too big a variation—a 1000 per cent. variation in ordinary language. As feet are divided into inches which are 1/12th as long, bels are divided into decibels which are 1/10th as big. One might object and point out that "decibel" is a longer word than "bel" but that is not too much extravagance in ink. A siren which emits a sound intensity of 10 bels emits a sound of 100 decibels. If sounds vary as much as .1 bel, about 29 per cent. in actual value, the ratio is 1 decibel. So as a means of convenience, of terse conversation, of ready comparison, the acoustic engineer through fine measurement technique discusses loudness of sounds referred to the threshold value of human ears as sea or zero level. He always knows that the zero level, the reference level of sound intensity, actually embodies 10^{-16} watts. To find the power of other sounds is then a matter of simple arithmetic. Long rows of ciphers and decimal points are avoided. They are, however, cleverly indicated by the number of bels.

Chrysler-Bell Siren

With war and the airplane attack, therefore, came the problem of very loud sounds, of sirens and super-sirens. The problem could not be approached in casual, hit-and-miss, "haywire" manner. Guns, planes, ships and tanks require great engineering skill and techniques. Here, too, the approach had to be technical and scientific. Accurate mechanical design, compressed air, horse-power, watts, bels and decibels had to be carefully considered and acoustic acuity of human ears had to be known about to achieve real results.

The Chrysler-Bell super-sirens, one of which is atop the R.C.A. building in New York, have been generally accepted as being highly successful. The acoustical engineering figures about it, which might appear overwhelming and super-technical, are really very straightforward. The siren is entirely a mechanical contrivance, powered by a 140-horse-power gasoline engine, and uses compressed air. In no wise is it electrical. For many years in acoustical science, sirens, organ pipes, whistles and tuning forks have been the general means of producing artificial sounds. In recent years telephone receivers and loud speakers driven by vacuum tube oscillators have become the vogue. Always the siren has employed a perforated rotating disk through which puffs of air or steam escaped to produce sound. The Chrysler-Bell Victory Siren employs a 30-inch rotating plate with six holes which chop, of course simultane-

ously, the blasts of air from six throats, each about two inches square. A total of 2,500 cubic feet of air per minute at a pressure of 5 pounds per square inch is driven out of the six throats. The "chopper" rotates at 4,400 revolutions per minute. The pitch of the sound is 440 vibrations per second.

It is appropriate to observe that although the siren is a mechanical device and sound waves are mechanical waves, all the techniques of measurement to determine whether the raucous sound produced by the Chrysler-Bell siren is effective are electrical. (See Fig. 1.)

A Super Stentorian Shout

The mythological Stentor had "a cry as loud as the cry of fifty other men." The Victory Siren has a "cry" equal in power to 4,000 million ordinary men or eighty million Stentors. These amazing comparative numbers result from straightforward considerations.

The sound power out of people's mouths is .00001 watt (10^{-5} watt). The aggregate sound power out of a giant loud speaker at a stadium might be 10 watts. The loud speaker aboard a boat which directed traffic at the international yacht races at Newport in 1934 emitted 500 watts (.67 HP) of aggregate sound power in the form of highly intelligible speech. This was one of the largest loud speakers that ever had been built.

The Chrysler-Bell siren's power in the form of a raucous sound is 42.2 kilowatts (56.5 HP). This siren then produces probably the most sound power ever artificially and continuously generated. Its sound is more intense than a thunderclap and various other extra-loud sounds. Close to the siren, the sound is not only powerful but dangerous, too. (Fig. 2.)

It is to be noted that the "total sound power" radiated by the Chrysler-Bell siren is 42.2 kilowatts. Of course such an enormous amount of sound does not come from a tiny aperture. Sound never comes from the theoretical point source. Actually the equivalent aperture of the super-siren is a circle 28 inches in diameter. Out of the big aperture all the 42.2 kilowatts of sound can be thought of as pouring.

As has been said, sound waves, light waves, radio waves and heat waves embody and carry power. Out of the equivalent 28-inch circular aperture of the super-siren comes 42.2 kilowatts of power. The midday July sun sends to the earth heat waves which are very warm. Actually the sun's radiation on an area of the earth's surface equal to the siren's aperture is only ½ kilowatt of heat wave power. The total power of the siren's sound radiation from the entire aperture is 42.2 kilowatts, and from a small area a bit larger than an aspirin tablet the intensity of sound radiation turns out to be 10 watts. So the calculation of the intensity of the sound compared to the threshold (10^{-16} watts) is very simple and straightforward. Ten watts equals 10^1 watts. 10^1 watts divided by 10^{-16} watts equals 10^{17}. This is then a ratio of intensities of 17 bels and of course 170 decibels. Of course this means that the intensity of sound from the super-siren is almost a million times a million times a million greater than that perceptible by the human ear. If it were 18 bels (180 decibels) instead of 17 bels (170 decibels), it would be the million times a million times a million ($10^6 \times 10^6 \times 10^6 = 10^{18}$).

With testing apparatus such as is shown in Fig. 1, it was found that at a distance of one mile the siren produced a sound of 100 decibel level, or 10 bels or one with 10 ciphers following greater than the threshold of audibility. Calculations indicate the sound level at 20 miles would be 60 decibels (6 bels) equivalent to that of ordinary conversation. At 75 miles, calculations reveal that the level would be about that of the threshold, in other words, just audible.

The sound intensity of the super siren is 4 bels (40 decibels) or 10,000

times greater than the threshold of pain. It is the most intense sound ever continuously produced by the techniques, the accurate knowledge and the manufacturing skill of man. Its only rival in intensity was the explosion of the volcano Krakatoa in the East Indian Ocean in 1883. It is recorded that the sound of that explosion was heard 3,000 miles away. It must have been many times louder than the Chrysler-Bell siren, since it is estimated that the siren could be heard, under favorable conditions, only 75 miles.

Intensity and Totality

Perhaps the reader has observed the repeated use of the phrase "sound intensity." To be accurate and explicit, in the discussion of sirens and sounds the engineer uses this phrase advisedly. "Bels" and "decibels" are used not to compare sounds—the total power of sounds—but rather the intensity of sounds. Of course the siren must send out a great deal of sound, but, more important, it must emit a very intense sound. As observed in the chart of "Sound Intensities" ordinary speech directly into the ear is more intense than a lion's roar at a distance of 18 feet. Of course the lion's roar embodies more sound than does speech, but the ear has no way of knowing how much sound is about; the ear can only give notice of how intense a sound is. Of course if the head is turned in a lot of directions and the ear hears considerable intensity at many angles, then of course one knows there is a lot of sound. It is therefore not completely correct to say, the Chrysler-Bell siren produces 17 bels (170 decibels) of sound. It does produce 56 horsepower of sound, but this amount of sound spreads out over a great area. Of course a siren must produce a great deal of sound, but likewise it must produce a very intense sound. It is more correct to say that the sound intensity of the siren is 17 bels.

In the days of the elevated in New York, not only was there a great deal of noise at 34th Street and Broadway, but also there was a deafening intensity of sound. At a baseball game in the Yankee Stadium there is at all times a great totality of sound, but not a great intensity of sound. This totality would not be measured in bels. All about us during the day, there is a lot of light—a really very large amount of light—but the intensity of daylight does not blind us, except when we look directly at the sun. A great modern searchlight pierces the sky at night with a brilliant, intense beam, but does not light up the landscape. The pantoscopic moonlight is not intense but does flood the entire country-side with a totality of light sufficient for reasonably good vision.

The pantosonority of a sound source is expressed in horsepower or kilowatts. The ratio of the intensity of sound produced at a given place, as compared to the minimum intensity perceptible by the human ear, is measured in bels and decibels. As shown in the chart, intensity of sound is completely specified in absolute —not relative—terms, by knowing the power per unit area—the watts per square centimeter. Horsepower per square inch would be another way to express it. Intensity is appraised by human ears and electrical ears (microphones). Totality is appraised by the integration of the brain.

So it can be accurately said that the Chrysler-Bell siren produces not only an amazing totality of sound but also an amazing intensity of sound.

Maximum Theoretical Intensity of Pure Tone

One might speculate as to the most intense sound that theoretically could be produced, that is, the most intense pure tone, a tone such as a good tuning fork tone. Of course the pressure of the air in the sound wave varies. That is what makes it a sound wave. The greatest

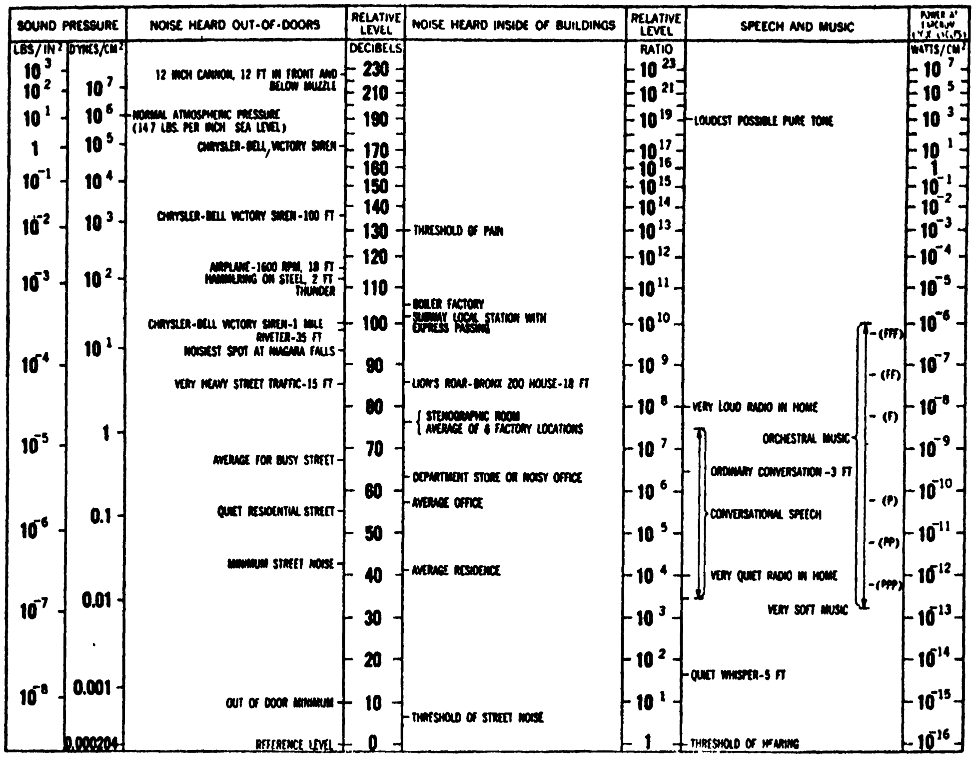


FIG. 3. INTENSITIES OF A NUMBER OF DIFFERENT SOUNDS

deviation below atmospheric pressure would be a vacuum—14.7 pounds per square inch less than normal. For a pure tone, then, the maximum pressure at a particular instant of time in the intense sound wave would be just double the atmospheric pressure, 29.4 pounds per square inch. This theoretical maximum intensity of sound would require a radiation from the area of an aspirin tablet of 1,000 watts instead of the 10 watts of the super-siren. The sound intensity would then be 19 bels (190 decibels). Of course the Krakatoa sound was not a pure tone. Its sound power must have been hundreds of kilowatts and its intensity many bels. The maximum pressure in its sound wave must have been many, many-fold greater than atmospheric pressure.

The pressure of tiny bits of postage against the eardrum was previously used to indicate the delicacy of response of the eardrum. Actually, in terms of pounds per square inch pressure on the eardrum, the value of ear threshold of pressure sensitivity is 3.5×10^{-9} pounds per square inch. The pressure in the sound waves at the aperture of the super-siren is calculated to be one pound per square inch.

Radio Waves and Sound Waves

To get 42.2 kilowatts (56.4 HP) into the sound waves radiated by the super-siren has been a fine achievement of mechanical design and compressed air technique. It was not a simple or easy task. It is provocative to realize that it has been much easier generally to put wave energy into the form of electric waves, radio waves, and send them out from an antenna. The 50,000 watts of a broadcasting station appears very big, and is the subject for a bit of boasting. In fact, 50,000 watts is only 80 horse-power, and 80 horse-power auto engines

are considered small and exist in great numbers. So in the general welter of the world's work 80 horse-power items are not big or extraordinarily powerful, but in radio engineering 80 horse-power transmitters are so regarded. In acoustical engineering, 80 horse-power would be a gargantuan value.

Some transoceanic radio telephone transmitters radiate about 75,000 watts or 100 horse-power. The super-siren puts a terrific and ear-splitting sound into the air with 56 horse-power. An everyday environment of sound of 800 Chrysler-Bell sirens scattered over the United States (the number of radio broadcasting stations in America) all day, would be unbearable. For short periods they serve excellently as an air-raid warning. Yet we move about comfortably close to radio antennas while powerful radio waves are impinging upon us. It is fortunate that humans have no radio ears, only acoustic ears.

Calculations indicate that the Chrysler-Bell siren can be heard 75 miles. Radio telephony across 3,000 miles of ocean is an everyday commonplace. Could a siren or a loud speaker be made so sonorific that it could be heard across the sea? Indeed it would be a terrible noise! The likely answer is "No." Furthermore a sound wave would require 4 hours to go across the ocean. Facile conversation would not be possible under attendant time delays. Only exploding volcanoes are heard 3,000 miles. Explosions of 12-inch modern cannon produce a sound intensity of 230 decibels (23 bels) at 12 feet; at this distance, the sound-wave pressure is about 500 pounds. They are heard across the English Channel, but perhaps 100 miles is the maximum range of their sound. The radio transmitter goes about its fine job with the passerby unaware. Radio apparatus and radio waves surely have many talents.

The intensity of the sun's heat waves on the earth's surface have been mentioned and are considerably lower in power content than that embodied in the sound waves at the equivalent radiation aperture of the Chrysler-Bell super-siren. It is interesting to ask what is the intensity of power in a radio wave necessary in radio transmission. For good reception by a good type of radio receiver, the radio wave power intensity arriving at one's receiving antenna should be at least 10^{-9} watts. This is quite a bit of wave power compared to the tininess of sound intensity which a human ear can hear, namely, 10^{-16} watts. It is 7 bels greater. Figuratively, human ears, then, could be said to be 7 bels more sensitive than an electrical ear, namely, 10^7, or 10,000,000-fold.

If very special antenna arrangements and very special radio receivers and vacuum tube amplifiers are used, as they are in transoceanic radio telephony, then the intensity of power in a radio wave can be less. In this case, the intensity of radio wave power can be as low as 10^{-19} watts and good results obtain. This 10^{-19} watts is 10^3, 1000-fold, or 3 bels less than the threshold intensity of the human ear.

Inspection of the chart, Fig. 3, will reveal a lot of interesting ideas about sounds, speech and music. It is to be continually remembered that sound waves are an embodiment of power and that the power of the sound in a just audible sound is the sea level of comparison for other sounds and that other sounds are so many, many times louder that, for purposes of easy calculation, ratios must be talked in terms of the decimal places and ciphers instead of the actual number. These decimal places and ciphers gave rise to the simple and convenient language of bels and decibels.

The alliance of acoustical science and techniques and mechanical engineering design and skill has given notably fine results. One thing is sure, the acoustical engineer has made the sound wave the Paul Revere of World War II.

FLIGHT IN THE DARK: A STUDY OF BATS

By ROBERT GALAMBOS

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For almost exactly one hundred and fifty years an unsolved problem has occupied a special niche in the minds of certain men of science. What type of sensory perception—what sense organ—informs flying bats of the location of obstacles to their flight? In the pitch blackness of the caves they inhabit, the eyes can be of little or no use for detecting objects; yet the location of ceiling, walls, etc., undoubtedly are perceived with ease and accuracy. The purposes of this essay are to cite some of the many attempts which have been made to resolve this problem, and to describe the experiments by which Dr. Donald R. Griffin and I have arrived at what we believe to be a simple and adequate explanation of the phenomenon.

In 1794, when the study of natural phenomena was burgeoning as never before, Lazzaro Spallanzani first recorded observations on the flight of bats. Having put out its eyes, he freed an animal in a closed room. It at once flew off and avoided walls, the ceiling, silk threads and "whatever other bodies which may have been placed about in an effort to embarrass him." Clearly these animals were equipped with a non-visual mechanism of amazing efficiency for detecting obstacles, and to the discovery of this mechanism Spallanzani directed his talent for devising simple yet fruitful experiments.

He eliminated, in order, the senses of touch, smell, taste and hearing. So far as could be observed, none of these treatments led to a significantly decreased ability to avoid, and consequently, he proposed that bats may possess a sixth sense whose nature is unknown and unknowable.

But contrary to what most people believe, Spallanzani did not maintain this point of view for very long. At his own request, the experiments were repeated by Louis Jurine, a Swiss entomologist, with very different results. Jurine found that bats with *plugged ears* invariably blundered helplessly into the same obstacles which were avoided with ease upon removal of the plugs. Therefore, according to Jurine, the ears directed bats—and Spallanzani promptly agreed. He happily discarded his theory of a sixth sense and accepted Jurine's explanation without reservation.

Meanwhile, Georges Cuvier advanced and warmly advocated the theory that bats possess in their wings an exquisitely developed sense of touch which, alone, was responsible for informing the flying animal of the location of obstacles. This hypothesis had received very careful experimental consideration from Spallanzani and his colleagues only to be rejected as an impossible explanation. Although Cuvier himself recorded no experiments in support of his theory, he clung to and reiterated the proposition with surprising tenacity. Upon reading any discussion by Cuvier on bats, one finds there a spirited refutation of the ideas of Spallanzani and Jurine and an assertion of the experimentally disproved touch theory.

The weight of Cuvier's authority has led scientific men ever since to conclude that (1) Spallanzani's work was haphazard and uncontrolled, (2) Spallanzani continuously supported the theory of a new sense, and (3) the bat detects obstacles by a sense of touch. None of these conclusions is correct. A complete discussion of the first two is the subject

of another article;[1] a rational explanation of the method used by flying bats to detect obstacles is the subject of the rest of this essay.

When Donald R. Griffin and I attacked the problem of obstacle avoidance by bats, we had at hand the results of many experiments performed since the time of Spallanzani. In practically every one of these, only qualitative results were described. Some impairment of ability to avoid was claimed to follow destruction of any sense organ, although it seemed clear that bats were most inexpert when their ears were plugged. Since, however, the exact degree of impairment of a given sense organ had never been stated in quantitative terms, we decided to measure the performance of bats in an obstacle situation whose characteristics were known and reproducible, to collect our data in a standard way, and to analyze our results by a rigid statistical test.

Furthermore, adequate consideration had never been given to the injury incident to elimination of the sense organs. Aside from the obvious fact that an injured animal is not likely to perform as well as an uninjured one, drastic operations make it impossible to restore the bat to normal in order to retest its performance. We planned, therefore, to render our bats blind, deaf, etc., in a strictly reversible manner, and to test the animals in the obstacle situation while normal, while blind or deaf and finally while normal once more.

The room we selected for the tests is a soundproof chamber in the Cruft Physics Laboratory at Harvard. Its dimensions are fifteen feet by eleven feet by eleven feet high; and the walls, ceiling and floor are well padded with soft sound-absorbing material. In a straight row across the center of this room, spaced one foot apart and hanging vertically from ceiling to floor, we suspended a row of steel wires. We selected wires with a diameter of one millimeter because this size has been shown to be about the smallest which bats can avoid. We hoped in this way to make our barrier difficult for even a normal bat to maneuver through, and thus to show up any impairment of ability in the operated bats at once.

A bat set free in this room would fly back and forth from one half to the other through the barrier of wires. As the animal did so, a count was kept of the number of times it hit and missed the wires. Each hit or miss was considered a trial. There was rarely any difficulty in judging these hits and misses, for when the bat struck, even very lightly, the observer could usually hear the noise caused by the contact of wing on wire and see the wire obstacle move back and forth under the impact.

In order to obtain data legitimate for analysis by statistical methods, it was necessary to make a large number of observations on each animal. A minimum of fifty passages through the barrier was found to be convenient and adequate for this purpose, but whenever possible more trials were recorded. The performance of the animal was then reduced to a score expressed as percentage of hits in the series of trials; if, for example, the bat hit the wires twenty-five times while passing through a total of seventy-five times, its score would be thirty-three per cent. A high score, therefore, indicates poor ability to avoid, while a low score indicates good avoiding ability.

Most normal bats when set free in the experimental room would fly back and forth, circling, swooping and dodging as if thoroughly at home. When their individual scores were determined, however, it was clear that some animals were much more adept at avoiding collisions than others.[2] Thus, of 129 *Myotis l. luci-*

[1] "The Avoidance of Obstacles by Flying Bats: Spallanzani's Ideas (1794), and Later Theories," by R. Galambos. *Isis*, 34: 132–140, 1942.

[2] For complete description of methods and results, see D. R. Griffin and R. Galambos, *Jour. Exp. Zool.*, 86: 481–506, 1941.

fugus tested, the lowest score (per cent. hits) was 7 per cent., the highest 65 per cent., and the average 35 per cent. We were apparently measuring a highly developed skill which reached its fullest expression in only a few animals.

In the next experiments we blinded the bats. This was accomplished in a painless manner simply by covering the eyes with a dark-blue solution of collodion; when, during the course of a minute or two the solvent evaporated, it left behind a hard layer of collodion through which the animal could not see. The collodion layer could be quickly removed with a wad of cotton soaked in ether, to restore sight to the animal.

Twenty-eight blind bats collided with the wires an average of 24 per cent. of the time, as opposed to 30 per cent. when completely normal. From these figures it is clear that blind bats are as adept in avoiding obstacles as normal ones. Some of them, in fact, showed marked improvement after being deprived of their eyesight, a phenomenon which appears to demonstrate that under certain conditions a bat's eyes are more a hindrance than a help.

Having thus substantially confirmed Spallanzani's original observations, we next set about to repeat the experiments of Jurine on the ear. To deafen a bat we at first used one to two techniques: (1) the ear flap was turned down and sewed to the head; (2) a drop of the collodion was placed in the ear and allowed to harden. Depending on which technique was being used, hearing was restored by cutting the threads holding the ear-flap or by poking a hole in the collodion.

Our deaf bats could not avoid obstacles. The average score of twenty-one deaf bats jumped from 28 per cent. when normal to 66 per cent. when deaf.[3] But the difference in these scores by no means portrays adequately the behavior of a deaf bat. The light touch of the finger which frightens a normal animal into quick, graceful flight has no effect whatever on deaf ones; they must be prodded with a stick. They are extremely reluctant to leave their perch and upon doing so flutter slowly and heavily through the air until they strike the walls, the wires or the experimenter. After the collision they continue fluttering helplessly, fall to the floor and there begin at once to scratch at their ears. The bewilderment of the deaf bat is complete.

All deaf bats recovered as if by magic when the use of their ears was restored to them, and their scores dropped at once to normal.

Cuvier and others have criticized experiments such as these on the grounds that the poor flight of the deaf animal is due to injury accompanying the deafening process. We believe this criticism is effectively answered by the demonstration that deaf bats perform normally when their hearing is restored to them, but to provide a final answer the following experiments were performed. Small glass tubes were fitted tightly into the external auditory canal and sewn firmly in place. Bats so equipped could hear only those sounds which passed down the inside of the tube, and by plugging this, we could cause deafness without further injury. The average score of eight bats, with unplugged tubes in their ears, was 32 per cent. This score is surprisingly low, considering the drastic change in shape of the auditory passageway caused by the glass tube. When the animals were made deaf by plugging the tubes with cotton threads, their average score rose to 67 per cent., and all the symptoms previously observed in deaf animals ap-

[3] We have determined what score might be expected from a bat completely unaware of the wires, by calculating the number of times an inanimate object with the average dimensions of a flying bat would strike if thrown at random at the barrier. A reasonable estimate is 65 to 70 per cent.

peared at once. Upon removal of the threads, each bat immediately returned to its previous level of performance. Since throughout these experiments, any injury or irritation was constant, we were forced to conclude that blocking the air passage to the bat's ear was solely responsible for the loss of dexterity in avoiding.

Having arrived at this conclusion, we turned to a suggestion advanced in 1920 by Hartridge. He proposed that the bat avoids by emitting sounds which echo off from obstacles and return to the ears, where these echoes give rise to appropriate sensations which inform the animal of the location of the obstacle. If this should be the explanation, we argued, then preventing bats from making sounds should render them just as helpless as plugging their ears. For if both sound production and sound reception are involved, elimination of either must lead to the same result.

We therefore tested bats which were unable to make sounds. They were rendered mute simply and quickly by tying thread around the snout while the jaws were closed. To make certain that no sounds whatever could issue from the mouth, we also coated the space between the lips with collodion. Eight bats, perfectly normal except that they could not open their mouths, were completely helpless when set free to fly. They fluttered slowly and cautiously about, turning and twisting, but eventually blundered into the wall or wires and fell to the floor. They were obviously just as inept at avoiding obstacles as their deaf brothers had been, and their average score was about the same (65 per cent.). When the threads around the mouth were cut, they at once flew off, swooping and gliding in a perfectly normal manner, and avoiding the wires with their previous skill.

Needless to say, these results excited us greatly. We were satisfied that the animals were uninjured, able to breathe adequately, and fully possessed of all faculties except speech. It is common knowledge that flying bats only rarely emit audible sounds, and yet our results clearly indicated that they used sounds to direct themselves. This could mean only one thing: bats in flight emit and direct themselves by sounds which we can not hear. Tests were in order, therefore, to see whether this was so.

Man perceives, as sound, frequencies of air vibration lying between about twenty and twenty thousand vibrations per second. These limits are apparently placed upon the human organism by the mechanical properties of the ear, and "sounds" with frequencies both above and below the limits of human hearing are known to exist. Below twenty cycles per second, air vibrations are "felt" rather than heard, and above twenty thousand cycles tones are too shrill to be audible. By definition, sounds above the upper limit of human hearing are called supersonic sounds. They can be detected by a variety of methods, the most convenient of which uses a thermionic amplifier to convert the supersonics into sounds we can hear. Professor G. W. Pierce, at the Cruft Physics Laboratory, is a specialist in the study of supersonics, and it was to him that we turned for the apparatus for our next experiment.

We borrowed from him one of the amplifiers which translates supersonic into audible sound. We placed it in our wire-strung experimental room and liberated a bat. The machine immediately gave out a great chattering clamor which continued so long as the animal was in the air. When the bat lighted on the wall, the chattering stopped, only to begin again when the animal took wing. We repeated this observation again and again with the same striking results. There seemed now little question that bats directed themselves through mazes of obstacles by using reflections of supersonic cries.

In order further to implement this explanation, we made a study of these

supersonic cries. We found them to be emitted by more than one hundred bats of four different species, thus amending the earlier statement of Pierce and Griffin that flying bats do not emit supersonic cries. The supersonic cries, furthermore, usually appear entirely independently of the audible cry and consist of a band of sound frequencies in the region of fifty thousand cycles. Each bat, we found, has a supersonic voice peculiar to itself as regards which frequencies are emitted and their relative intensities. The duration of each cry is very brief, being less than one fiftieth of a second long. Bats on the wall, preparing to fly, produce fewer than ten cries per second, but when in flight and especially when the animals approach an obstacle, the cries are emitted at astonishingly high rates.

The most important support for the theory that the cries play a part in the obstacle-avoiding mechanism comes, however, from the fact that just before normal bats successfully fly past the wires an abrupt drop in rate of emission of cries takes place. The drop—from about fifty to about thirty cries per second—is sudden and unmistakable. In cases where the bat strikes the wires, this drop is rarely observed. And when deaf bats fly, the drop in rate never takes place; in fact, deaf animals keep up a constant succession of cries at a single monotonous rate all the time they are in the air.

The question at once arose as to the source of the supersonic cries. Tying the mouth shut renders bats incapable of avoiding obstacles, as we have already seen; this is clear evidence that the sounds issue from the mouth. To make certain of this point we liberated mute bats in the room containing the supersonic detector and found the cries to be reduced to a very feeble intensity. We then demonstrated that the supersonics issue only from the mouth by immersing all except the head of a normal bat in water; the cries were very loud. When we immersed only the head, on the other hand, no supersonics could be detected in spite of the violent struggles of the animal.

The production of supersonic sounds by animals is a matter which has received practically no study, chiefly because of the technical difficulties involved. Certain insects have been shown to make supersonic sounds, but they appear usually to be merely accidental by-products, *i.e.*, harmonics, of the audible chirp. Almost nothing is known about high-frequency sounds in mammalian cries. We were naturally interested to discover the way in which the bat cries are produced, and to this end we consulted the literature for anatomical studies on the bat larynx. We found, in a paper by Elias,[4] a complete description of this organ taken from species related to ours. Elias, writing over thirty years ago, was astounded by the excessive development of the larynx in bats. The laryngeal cartilages have become almost completely ossified, and extremely large muscles are attached to the voice box in such a way that their contraction must lead to great tension on the vocal cords. The vocal cords are different from those in most mammals, being very short and tough, and extremely thin. Elias concluded that all the morphological peculiarities of the larynx are directed toward increasing the pitch of the cry emitted, and that from the anatomical point of view there is every reason why the bat audible cry should be a very shrill squeak. From the way he writes, we feel confident that if he were told bats actually emit sounds of such high pitch as to be inaudible to man, he would not be in the least surprised.

Let us recapitulate briefly the evidence so far advanced for the auditory theory. (1) Bats can not avoid obstacles if deaf or if unable to use their mouths. (2) Bats give voice to supersonic cries. (3) A characteristic change in the rate of production of the supersonic cries occurs

[4] H. Elias, *Morph., Jahrb.*, 37: 70–119, 1907.

when bats avoid obstacles; this change is almost always absent when normal bats strike the obstacles, and it never occurs when deaf bats fly about. These facts can be explained by the auditory theory alone, but with them its proof is not yet complete. For a fully adequate solution, evidence is required that bats hear sounds which lie in the supersonic range. This evidence has been obtained by recording cochlear potentials from bats in a way which will now be described.

The ear of mammals has three separate chambers, named, in order from the outside in, the outer ear, the middle ear and the inner ear. The inner ear is more commonly known as the cochlea, a spiral of thin bone containing extremely complex structures which actually analyze sounds.[5] The most important of these structures are probably the cells which lie on what is called the bacilar membrane. These cells, called hair cells, are set into motion by the sound waves which have been conducted to the cochlea from the outside air, and in some as yet unknown way they initiate the impulses of the auditory nerve which, upon arrival at the brain, are eventually interpreted as sounds. The hair cells, thus charged with transforming physical vibrations into the stuff of which sensations are made, form an important link in the chain of events which is the concern of the auditory physiologist.

Some years ago, it was found that when sounds fall upon the mammalian ear, electrical oscillations arise in the cochlea. These oscillations, called cochlear potentials, have been traced to the hair cells, and it is now commonly agreed that the site of origin of cochlear potentials is the stimulated hair cell. In order to orient the reader to the somewhat complicated technique of measuring these potentials, it will be advisable to describe briefly the standard technique for obtaining and recording them.

The cochlea of an anesthetized animal is exposed and a strand of wire is placed against it. Another wire is placed in contact with indifferent tissue—usually the skin underlying the incision. These two wires, called electrodes, lead to an amplifier which magnifies potential differences and activates some type of recording system (loudspeaker, galvanometer, etc.). Differences in potential occur between the two electrodes whenever sounds are presented to the ear, and it has been found that these potentials duplicate the wave-form of the sounds with a high degree of accuracy. Thus if one speaks into the ear of the animal, the voice is clearly recognized as it issues after amplification from the loudspeaker. The same fidelity of reproduction occurs when pure tones are presented, and the entire phenomenon disappears when the cochlea is destroyed, its circulation impeded, or when the animal dies.

The relation of the electrical activity of the cochlea to hearing is still somewhat obscure. The sensation of hearing clearly involves many more factors than the changes taking place in the auditory end-organ, and the question has been raised, therefore, as to whether the mere demonstration that cochlear potentials arise when a sound is made is sufficient evidence that the animal hears the sound. Attempts have been made to settle this point, and, although they have not led universally to the same conclusion, it may be stated that animals probably do perceive only those sounds which cause cochlear potentials. The best experiments, for instance, show that cats and dogs respond to sounds up to about thirty-five thousand cycles or so, and it is possible to record cochlear potentials in these forms up to, but not much beyond, thirty-five thousand cycles. Studies of this sort have never been made on bats.

[5] In this discussion I follow the interpretations of S. S. Stevens and H. Davis in their book "Hearing," published in 1938.

To measure cochlear potentials in bats, a supersonic generator which produces pure supersonic tones, and a supersonic microvoltmeter capable of detecting and measuring high frequency cochlear potentials, were put at our disposal by Professor Pierce. We have been able to demonstrate that the bat cochlea produces potentials having the same frequency as the sound wave for sounds up to at least ninety-eight thousand cycles.[6] The apparatus used can not measure potentials of higher frequency than this, and there is every reason to believe the bat cochlea can convert sound into electrical waves for still higher frequencies. Cochlear potentials have previously never been observed in mammals to sounds above thirty-five thousand cycles. Our results, studied in more than thirty bats of four species, clearly offer strong support to the theory that bats hear supersonic sounds, for it would be a remarkable coincidence indeed if the highly unusual electrical properties of the bat cochlea were not in some direct way connected with an ability to perceive supersonic cries.

It is significant to note that this result was recently predicted on anatomical grounds. Ikeda and Yokote, two Japanese investigators, concluded from their study of the Japanese bat, first, that the bat cochlea is unique among mammals in having extraordinary morphological peculiarities in that region of the basilar membrane which is excited by sounds of high frequency, and second, that these peculiarities are of such a nature as to make it very likely that bats hear very high-pitched sounds. They tried to establish this point by experimentation, but failed due to technical difficulties.

Auditory Theory of Bat Obstacle Avoidance

We have seen how three lines of experimental evidence converge upon the auditory theory as an explanation for bat obstacle avoidance. In the first place, bats can avoid obstacles only so long as they have the use of their mouths and ears; if the ears are plugged or the mouth tied shut the animal performs as if with no perception whatever of obstacles in its path. In the second place, the flying bat not only produces cries inaudible to man, but in normal bats a correlation is demonstrable between the way in which the cries are produced and the location of the bat with respect to obstacles. This correlation is not shown by deaf bats or by normal bats which strike obstacles. Finally, the bat cochlea generates potentials when supersonic sounds are presented to the ear, a property not possessed, at least not to so high a degree, by any other known mammalian auditory organ.[7]

This experimental evidence can not be adequately explained by any theory other than the auditory theory. It will be necessary, therefore, to present this theory in a more specific way.

We propose the following as a résumé of the auditory theory. The supersonic cry of the flying bat permeates the space through which the animal will presently fly. Objects in that space scatter the sound waves, some of which then return to the ears of the animal and are perceived as sound. Some characteristic of the pattern of the reflected waves indicates to the animal the precise location of the objects, and it then suitably alters its course so as to avoid them.

Many statements in the preceding paragraph could profitably be amplified. It would be interesting, for instance, to

[6] R. Galambos, *Jour. Acoust. Soc. Amer.*, July, 1942.

[7] In addition to these three lines of evidence, the auditory theory receives support from the descriptions of the bat larynx by Elias (footnote 4), the bat ear by Ikeda and Yokote and the bat brain (by Poljak). Poljak (*Jour. Anat.*, 60: 465–469, 1925), characterizing the cochlear nuclei in the bat brain as "excessively large" and the optic tracts as so reduced as to be almost vestigial, concluded that all the anatomical facts pointed toward a marked dominance of the sense of hearing in bats.

demonstrate just how the remarkable ability of bats to avoid obstacles arises in part out of peculiar directional and reflective properties of supersonic sounds, and to point out how if bats were to use audible sounds this would lead to a very much reduced ability to avoid. But only one statement will be treated here; namely, that some characteristic of the pattern of the reflected waves indicates the location of the obstacle. What is this characteristic, and how does it serve its important function?

There appear to be two ways in which the bat might be informed of the exact location of the obstacle. Let us assume the animal flies head-on toward a wire; the echo from the obstacle will arrive at both ears simultaneously. If the head should be turned slightly to one side or the other, however, the path traversed by the sound would be slightly longer for one ear, and the sound would therefore strike the near ear a fraction of a second before it arrived at the far ear. The bat, having presumably learned by long experience, would know at once that the obstacle lies on the side of that ear which first perceived the sound. In order to locate the obstacle exactly, it would then turn its head so as to receive the echo simultaneously in both ears. If the bat located obstacles by this method, it would be using as a cue what is technically known as the difference in time of arrival of the sound at the two ears.

But there is another possibility. Let us suppose the bat approaches the wires with its head turned slightly to one side. The echo would travel to the near ear by a free, unobstructed path. The far ear, on the other hand, with the snout and head interposed between it and the wire, would lie in a "sound shadow" cast by these structures. This would simply mean that the sound intensity at the ear in the shadow would be less than that at the other ear, and the bat could locate the wire by orienting its head so that the intensities at both ears were the same. It would thus localize the sound source by the so-called intensity difference method.

Either of the above explanations is a likely description of the auditory mechanism by which bats locate obstacles,[8] and there appears to be no way at present to evaluate them. It would be convenient here to resort to the subterfuge commonly used by biologists when faced with a problem of this sort; namely, to render a judgment in a particular case by citing experiments on other animals where the given phenomenon has one and only one explanation. Unfortunately, it is not possible to lean on such a device here. Dogs, cats, birds, etc., are known to possess remarkable powers for locating the exact sources of sounds, but no one has yet shown that time difference, not intensity difference (or *vice versa*), is the sole explanation. Lacking even this type of evidence, therefore, we must conclude that time difference, or intensity difference, or both, constitute the mechanism whereby bats determine the precise location of obstacles in their path.

This uncertainty does not weaken the auditory theory in the least. The exact cue is, after all, a matter of subsidiary importance, however interesting it may be in itself. Bats possess anatomical structures which are peculiarly adapted for producing and receiving supersonic sounds; they emit supersonic cries when in flight, and they can not avoid obstacles if their ears or mouths are covered. Regardless of how one may choose to arrange these facts, he is driven to conclude that the ears serve to direct the bat as it flies in the dark.

[8] Localization by the difference in phase method is extremely unlikely because of the short wave-lengths involved. See Chapter 6 of the author's doctoral dissertation, "The production and reception of supersonic sounds by flying bats," on file at Widener Library, Harvard University, Cambridge, Massachusetts, for a complete discussion of these matters.

CALENDARS AND CALENDAR REFORM

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SOMETIME we shall be called upon to reshape the organization of the world so as to insure a lasting peace and promote the general welfare of mankind. It is well that we begin to think about that reorganization and to consider what changes, if any, would contribute to the welfare and happiness of mankind in general, for isolation is no longer possible for any part of the globe or any section of the human race. Our destinies have been for all time united by science and invention, which have diminished the distances between continents. One of the devices which make possible an orderly existence of men in social groups is the calendar.

The calendar by which we measure the passage of time and the recurrence of the seasons possesses several serious defects capable of remedy, if all men could reach an agreement as to what changes are desirable, and the proper time for making them. This, however, is not easy of attainment, for our present calendar is one of the basic structures of our civilization and such structures are not easily changed. They constitute the framework of all our social institutions, which has reached its present state by a long process of evolution, and such a framework, age old in its development, should be altered as little as is consistent with progress.

All peoples who have engaged in agriculture of even the most primitive sort have felt the need of a system for measuring time and predicting the recurrence of the proper seasons for planting and harvesting crops. Around an agricultural calendar they have arranged a program for religious rites, feasts, dances and other celebrations designed to influence and propitiate the unseen powers thought to control natural processes.

The most obvious means for measuring time are the movements of the heavenly bodies, sun, moon and stars. A calendar based on one or more of these has regularly been formulated by a primitive people emerging from barbarism.

The most conspicuous of the heavenly bodies, the sun, not only defines the year from one seeding time to the next, but also from one sunrise to the next defines the length of the day. Since day and night are in the long run of approximately equal length, it was natural that each should be divided further into hours, the number of which was set at 12 of daylight and 12 of darkness at or near the equator, where day and night are approximately equal, and where the problem first presented itself to the human mind. The subdivision of each hour into 60 parts, minutes, and each minute into 60 seconds is a device handed down to us from ancient Babylonia.

Next in importance to the sun as a measure of time is the moon. Its recurrent cycles give us the months, each cycle covering about 29½ days. Twelve such cycles aggregate 354 days or some 11 days short of a solar year.

Since the solar year does not correspond exactly with any definite number of lunar cycles, it is impossible to combine lunar months into a solar year with exactness. The nearest approximation is obviously a 12-month year, although it includes only 354 days. Different peoples in their calendars have used months of arbitrary length ranging in duration from 20 to 31 days.

The Maya of Central America used a

20-day month, although they were aware that this did not correspond with a true lunar cycle. Their solar year contained 18 such 20-day months, aggregating 360 days, a closer approach to the true number of days in a solar year than is given by 12 true lunar months. The Maya added 5 extra days to their 18-month year to make a solar year of 365 days. These extra 5 days however were not deducted from the ensuing month, so that the succession of months went on independently of the seasons and no attempt was made to have them come out in harmony. Spring began in whatever month happened to be current, its arrival being determined by the alignment of the sun with certain carefully placed stones.

Our present calendar came down to us from the Romans who in turn had it from the Greeks and Egyptians in large part. As revised by Julius Caesar at the beginning of the Christian era, the Julian calendar consisted of 12 months of varying length. The mean length of the solar year was recognized on astronomical evidence as being 365¼ days. Ordinary years were accordingly made to contain 365 days and an extra day was added in the shortest month, February, every fourth year. The month of July was so named in honor of Julius and it contained 31 days. February was assigned 29 days in ordinary years and 30 in leap-years. But Augustus the successor of Julius renamed the month succeeding July, August in his own honor and in order to give it equal importance with July in the calendar lengthened it to 31 days. So it was necessary to borrow a day from the shortest month, February, which thereafter had 28 days in ordinary years and 29 in leap-years, as it still does.

Thus was arranged the so-called Julian calendar which persisted unchanged for more than 1500 years, and except for a single modification still persists with us.

In estimating the length of the solar year as 365¼ days, Julius had made it too long by 11 minutes and 14 seconds, as more exact astronomical observations have shown, and in 128 years the error would amount to an entire day. The erroneous days continued to pile up century after century until in 1582 the matter was taken in hand by Pope Gregory XIII. He ordered the extra days to be cut out, ten of them, bringing the beginning of the year back to where it was at the beginning of the Christian era. To provide against a renewed over-correction of the calendar by leap years, Gregory directed that leap year should be omitted in all centenary years except those which are multiples of 400. Thus the year 1900, though divisible by 4 was not a leap year, but 2000 will be because it is a multiple of 400. Such is the present status of our calendar.

According to modern astronomy, however, a slight over-correction by leap years still persists in the Gregorian calendar. To eliminate this it has been proposed to make the year 4000 and all its multiples common (not leap) years. With this modification the beginning of the year will not vary from its present place in 200 centuries (20,000 years), which is good enough! The leap year rule, as thus qualified, would run as follows: Every year the number of which is divisible by 4 is a leap year, excepting the last year of each century which is a leap year only when the number of the century is divisible by four; but 4000 and its multiples 8000, 12000, 16000, etc., are by a further exception common years.

Pope Gregory's reform of the calendar in 1582 was promptly accepted by all Roman Catholic countries, but in the 16th century religious prejudices were very strong. Protestant England refused to take orders from Rome either on the calendar or on any other subject and thus a desirable reform was delayed

in all English-speaking countries for two centuries. The Eastern or Greek Catholic church was even more obdurate and still adheres to the Julian calendar. The Julian calendar was in use in the North American colonies, as in all other parts of the British Empire, until shortly before the American Revolution. Thus George Washington was born on Feb. 11, 1731, of the Julian calendar and he himself always regarded Feb. 11 as his birthday. But the error in the Julian calendar amounted to eleven days when Great Britain switched to the Gregorian calendar and so Washington's birthday became February 22 of the current calendar.

A complication in the measurement of time and in calendar making, which we have not yet considered, is introduced by the seven-day week. This arises not from astronomical but from social and religious considerations. Occasional days of rest and recreation are essential in a well-ordered society. In various parts of Africa, weeks of four, five, six and eight days are observed by the natives, usually in connection with a recurrent market day. The seven-day week originated in western Asia and spread to Europe and North Africa with the spread of the Jewish, the Christian and the Mohammedan religions, which agree in having a seven-day week though with a different holy or rest day in each.

Neither the 365-day year nor the month of 29 or 30 days is exactly divisible into seven-day weeks, so that in our present calendar each successive New Year's day falls on a different day of the week. Every other event which falls on a particular day of the month falls on a different week day in each successive year. This is only one defect but a serious one of our present calendar, and it is capable of eradication in a very simple way, as we shall see.

A second defect of our calendar arises from the varying numbers of days in the month. In the shortest month, February, it is 28 or in leap years 29. In certain other months the number is 30 and in the rest 31. One has to go through the lines "30 days hath September" etc., before he can feel sure how many days there are in the current month. Even then he can not tell without a calendar of the year before him how many Sundays, how many full weeks and how many week days there are in the month, since these change from year to year. All these items are of importance to the business man, the schools, the churches, the banks, and all of us. There should be no uncertainty concerning them and there need be none under a slight modification of the calendar, which would make every day in every year the same as regards the day of the week and the day of the month. To bring about this desirable uniformity, two different but related plans have been proposed. They are known as the 13-month calendar (a proposal now withdrawn) and the World calendar. The 13-month calendar would make every month of exactly the same length (four seven-day weeks) so that it would begin on a Sunday and end on a Saturday. The number of work days in each month would then be the same, except for the occurrence of special holidays. The standard year would thus consist of 52 seven-day weeks, would always begin on Sunday and would end on an extra Saturday as a 365th day. Another extra day would be added in leap years. But with these desirable features is included one serious disadvantage. The year is not divisible into equal half years or quarters, since thirteen is an odd number of months.

This difficulty is avoided and most of the advantages of the 13-month arrangement are retained in the proposed World Calendar. This retains the familiar 12-month year, and divides it into four quarters of equal length. Each quarter

begins on Sunday and ends on Saturday. It contains 3 months including 91 days, in its 13 weeks. Month dates always fall on the same week day from year to year. Each month has 26 week days plus Sundays, a uniformity very advantageous to business.

The first month of each quarter begins on Sunday and so contains five Sundays.

PROPOSED WORLD CALENDAR

FIRST QUARTER

	S	M	T	W	T	F	S
JAN.	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31				
FEB.				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30		
MAR.						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30

FIG. 1

The other two months of the quarter contain four Sundays each. Each quarter thus includes 13 Sundays.

The first month of each quarter consists of 31 days (including the extra Sunday). Each of the other two months of the quarter consists of 30 days. The three months of each quarter are thus alike in length except for the extra Sunday of the initial month.

Each quarter includes 91 days, and combined the four include 364 days. An extra Saturday, a holiday called Yearday follows Dec. 30th and this makes the 365th day of the standard year, as in the 13-month calendar.

In leap years an extra Saturday, Leap-year day, a holiday, follows June 30th in the middle of the year, making a 366th day.

A world calendar thus revised would be "balanced in structure, perpetual in form and harmonious in arrangement." Only one group of business men is likely to object to it, those who print calendars, for their business will be greatly reduced. Each year's calendar will be the same, except for the extra Saturday in the middle of each leap year. Educators, scientists, and professional men would welcome the adoption of the world calendar which would greatly simplify the arrangement of schedules and appointments.

Holidays such as Easter could be stabilized and given a fixed place in the calendar, preferably at the week end so as to make 2-day or 3-day periods of recreation possible without breaking into the working week. Easter of course comes on Sunday, Christmas would come regularly on Monday, Washington's birthday could be moved to the day which he celebrated, the 11th of February, Lincoln's birthday would come on the following day, Sunday February 12, or if celebrated on Monday, the 13th a single national 3-day week-end holiday in mid-February would result. Labor day naturally falls on Monday, Sept. 4, national election day could be fixed on Monday, November 6. Armistice day might well be celebrated, as in England, simply by a 2-minute pause on Saturday, November 11th, and Thanksgiving day could be stabilized on Thursday, the 16th of November, or preferably advanced to the 18th, Saturday, or the 20th, Monday.

The 17th of March, St. Patrick's day to Irish Americans, and Evacuation day

to all Bostonians, since Washington forced the British soldiers out of Boston on that date, would fall on Sunday and its celebration probably on Monday. Only the 4th of July (Wednesday) and Columbus day (Thursday) would remain as mid-week holidays widely celebrated in the U. S.

By way of summary, we may note that the chief source of the imperfections of our present calendar lies in the attempt to use simultaneously three different methods of measuring time (1) the solar year of 365 days, (2) the lunar month of 30 days more or less, and (3) the conventional 7-day week. No two of these come out in agreement.

We can not get away from a solar year of slightly more than 365 days, since on this the recurrence of the seasons depends. Our problem then is to bring into conformity as nearly as possible with the solar year both the months and the weeks. Our present calendar does neither of these things adequately. To make up a year of twelve months we have to adopt months differing in length by as much as three days, which is poor time engineering. To make up a year of 365 days we have 52 seven-day weeks, with one day left over. By beginning the next week on this left-over day, each successive year begins on a different week day. We are confronted with the same difficulty as regards the day of the week, as confronted the Maya regarding the months in relation to the year. Instead of skipping the five extra days at the end of a year, and beginning a new year with a new month, they made the five extra days part of a new month and thus there was no correlation between a particular month and a particular part of the year. And we, instead of skipping the left-over day at the end of the year and beginning the new year with a new week, keep the succession of seven-day weeks uninterrupted regardless of what it does to our yearly calendar.

The difficulty concerning the lack of agreement between days of the month and days of the week in successive years is met in both the proposed 13-month calendar and the proposed World calendar in the same sensible way. The extra day at the end of the year is not put into a seven-day week, but is made a special holiday, a year day or extra Saturday, as you choose to call it. The extra day of leap years is treated in a similar way, as leap year day which does not make part of a seven-day week.

The variation in length of the months in our present calendar is obviated in a different way in the 13-month calendar and the World calendar. In the former each month would consist of exactly four weeks, 28 days, the total being 364 days, with year day not a week day, making the 365th. The impossibility of having quarter years made up of like numbers of months is the chief defect of this proposed calendar.

In the World calendar, there would be four equal quarter years of 91 days each, with one extra year day making the 365th.

Every month would contain the same number of week days (26) and the same number of Sundays (4) except the first month of each quarter which would contain a fifth Sunday, the odd or 91st day of the quarter.

How and when could we change from the present to the proposed World calendar with the least amount of disturbance to existing conditions? January 1, 1945 would be a practicable date, since that would be the same day of the week, Sunday in both calendars.

Of course no country single handed could bring about the change. It will have to be by joint action of a large part of the civilized world. Already 14 nations have officially approved the World Calendar. In response to a proposal made by Chile and sent to all governments by the Council of the League of Nations in 1937, favorable

replies were made by six American governments, *viz.*, Brazil, Chile, Peru, Uruguay, Mexico, and Panama; as well as by Esthonia, Greece, Hungary, Norway, Spain, Turkey, Afghanistan and China. If the United States and Canada were to join with Mexico and the South American Republics in adopting the World Calendar, it seems highly probable that the rest of the world would soon accept it. There is no religious opposition in sight today as there was when Pope Gregory instituted his reforms, nor is there ground for political opposition. Nothing but the inertia of custom holds back a reform which would benefit all classes of people, not least of all students and teachers.

MYSTICISM IN SCIENCE

By Dr. R. S. UNDERWOOD
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TENSE and expectant, the audience watches. Quickly the magician opens the lid of the narrow vertical box which has just closed so suddenly upon his startled assistant. There hasn't been time to arrange a trick, and he seems frightened. Something must be wrong. It is. The girl is gone—vanished. No—there she comes out of a far door, no longer in a strait-jacket, but pert and free in shorts and spangles.

The tension relaxes.

"I'm sorry," explains the magician. "I didn't mean to say 'hocus pokus' quite so fast."

The crowd laughs. It is superior now. Everybody knows that the stock magic phrase had nothing whatever to do with the unaccountable disappearance of the girl.

But suppose the trappings of the act had been altered a little. Suppose the chief actor had worn an exotic head-covering and had called himself a Brahman seer. Suppose he had explained gravely that it is possible, by the new vibratory technique, to waft his subject temporarily into the fourth dimension. In that case it is likely that he would have gained a credulous convert or two. Of course nobody would know for sure what he had really meant, least of all the seer, but the intriguing name of the obviously effective cause, the redoubtable fourth dimension—fairly reeking as it is with intellectual content—would be very, very impressive indeed. The prestige of science, striking obliquely here, would help the subtle explanation to get a respectful hearing. Mysticism and science, combined, make a well-nigh irresistible team.

For mystery has a glamor of its own. Consider the very number of synonyms for "mysterious" in my small and abridged dictionary: "abstruse, cabalistic, dark, enigmatical, hidden, incomprehensible, inexplicable, inscrutable, mystic, mystical, obscure, occult, recondite, secret, transcendental, unfathomable, unfathomed, unknown." There, in the staid dictionary, you have a glimpse of the thought patterns of humanity, of the almost tangible awe which clings like a persistent cloud about that which is not understood. In a page of brief definitions this sudden deluge of words clearly shows where fascination lies. The human race is mystic to its very core.

But obviously an idea so many-faced as "mysticism"—so broadly tangled with the hopes, fears and confused thinking of mankind, can not go into the premise of a logical train of thought unless we compress it somehow into an understandable unity. For the purposes

of our discussion we must chop the word clear of its subtle fringes of meaning. Two major ideas will remain, the first one signifying utter sham, as pompous and pretentious as it is amusing; while the second connotation—the one which remains respectable under scrutiny—is the mysticism which lies at the heart of modern science. We shall come to that later.

But first of all let it be understood that we are not here concerned with the simple, folksy brand of mysticism which would connect a case of measles with the path-crossing activities of the neighbor's black cat. Superstition can naturally have little to do with science, which, again according to my dictionary, means "knowledge verified by exact observation, and thinking which harmonizes with that knowledge." For obviously it is not exact observation and exact thinking which has established the dubious connection between a pinch of salt thrown over the left shoulder and a subsequent windfall on bank night, or between not sitting on a handkerchief and a run of flat hands at the bridge table.

No, the mysticism of which we write is so far from crude and naive superstition that it has actually an intellectual front, an air about it, so to speak. It is nurtured by scientific phrases and a specious imitation of learning. It has a subtle, seductive quality which inevitably traps the would-be sophisticates who fawn before impressive but indigestible ideas. It is astrology, it is the fourth dimension, it is curved space, it is non-existent or misunderstood profundity. It is the invoking of a cause for a given result which merely makes that result somewhat more incomprehensible than before, like the above use of the "fourth dimension" to account for the magician's vanishing trick. It is muddle-headedness disguised as insight. It is fraud, though in its subtler phases it fools us all now and then.

Take astrology, for instance, which accounts for the rundown condition of John A. Fitz as being due to a bad combination of the planets. This explanation is not satisfactory to the astronomer, who studies the celestial bodies themselves instead of their effects upon the human disposition; who misses, somehow, the direct connection between Mars and the human midriff; and who also misses, sometimes quite terribly, the cash that he might collect from eager and opulent customers who want to know all about the planet Saturn and its thrilling evil influence. But the explanation, nevertheless, may sound convincing enough to John A. Fitz himself, who, even though moderately well informed and equipped for everyday living, does not, unfortunately, know enough about the planet Jupiter to absolve it of all blame for the past affairs of his wife. Here (thinks John) is a fellow who knows first hand about the stars and their effects upon people, and who is John A. Fitz to question the findings of the savants? After all, science is a wonderful thing. Better be safe than sorry; better pay the man for the horoscope. Thus one more victim of scientific mysticism pays his tribute to muddled thinking.

And yet the really adult members of society will not, for the most part, be fooled by this particular brand of mysticism. While it is conceivable that a clerk in the Outer Offices of the Grand Planner may keep a careful record of astrological predictions, and may do his level best to bring to pass those which do not contradict each other, it nevertheless seems evident that this delightful theory needs some fairly substantial support from unbiased records. And one of the more or less patent facts of general knowledge is that history is strangely lacking in accounts of a mammoth statistical campaign, involving the dispositions and destinies of millions of human beings, during which the star prophets

got their data. Without such data their conclusions would be worthless even if they were not absurd to begin with in the light of astronomical facts. The intelligent man in the street may not know about the absurdity; but he is likely to sense the dubious nature of the evidence when he learns, sooner or later, that astrology and astronomy are not really the same, and that it is only the astronomers who have access to the large telescopes of the world. Thus he learns that the bolstering statistics which the astrologers lack are not even now being gathered for them. And thus, if he has reasonably good judgment, he decides to worry along without his horoscope.

This being the case, we can dismiss rather lightly the mysticism of the sky-charlatan. He could never, never deceive the intelligentsia to whom this essay is directed. And incidentally, we can explain with airy ease the widespread vogue of astrology to-day. The explanation lies chiefly in the bread-and-butter urge of numerous national newspapers and magazines to share in the golden harvest reaped from the bamboozling of the more lightheaded public, together, of course, with the generous supply of lightheadedness itself. Surely it is astrology which gives the final and clinching demonstration of Puck's pungent phrase: "What fools these mortals be!"

But what of the girl who was wafted into the fourth dimension? Isn't this a deeper problem? Since reputable mathematicians often speak quite learnedly and seriously of this thing called "four-space," why can't it be possible that physical objects now and then slip out of the ordinary three-dimensional framework which seems to represent reality to our limited faculties, and that they become therefore invisible, though really right at hand in the fourth dimension? Sounds plausible, doesn't it? Well, there we have a perfect example of the illegitimate type of scientific mysticism, of the impressive-sounding explanation which leaves the explainee two thirds addled, half convinced and wholly in the dark. The loophole for sanity, as is often the case, lies in recognizing the prostitution of words. When the mathematician talks of four, five and n dimensions he is simply speaking of four, five and *n independent variables*. The three dimensions of a room, described roughly as length, width and thickness, or up-and-down, right-and-left and backward-and-forward, represent the first simple space concept associated with the word "dimension"; and the desertion of this concept for a new meaning applied to the old word is the cause of the whole sorry confusion. It is this change of meaning which allows us to speak of *time* as a dimension; and it is still true that, outside of useless and metaphysical speculation, there are three and only three dimensions of *space*. The fourth dimension of mystic significance is as nonsensical as the fourth corner of a tin triangle.

Not that the mathematicians themselves are blameless. Just as they talk unfairly about "dimensions" with secret reservations in their hearts, so also they prate of "four-space," "five-space" and, of course and inevitably, their beloved "n-space," where as many variables as they please can shoot out along n mutually perpendicular lines. Actually they know what they are talking about (we hope), but again they have swindled the public. And sometimes we fear that, in their enthusiasm and forgetfulness, they may possibly have swindled themselves.

It all comes about because in "analytic geometry" they have invented a beautiful way to illustrate the equations of algebra with the points, lines, curves and surfaces of geometry. This works wonderfully on a plane, where the relative sizes of two varying quantities can be

illustrated with lines and curves. It still works in actual space with its three dimensions, in which the illustrating figures can be neatly approximated by means of strings and paper surfaces. But when four or more variables are used, this picturing device flatly and utterly fails. Yet the investigator finds that he can continue to make algebraic discoveries by using algebraic devices which were suggested by the geometric pictures in the cases where those pictures applied. Then what does he do? To help his thinking, and heedless of the fraud he is perpetrating, he denies that he has gone out of geometry, and he begins to talk mystically of such things as "hyper-spheres" whose intersections with planes are spheres. Neither he nor any one else can draw pictures of such monstrosities. Intoxicated with his verbiage, he begins to see Alice-in-Wonderland "four-space" on the horizon; and soon he putters around in "n-space" as casually as a child with a pile of blocks. And by this time he may actually have forgotten that his picturing device ever did break down, and that he is not still using a mystic sort of geometry in his thinking.

Please do not misunderstand me. I cast no aspersions on the beauty and usefulness of the mathematical results thus obtained. My objection is solely to the terminology which implies that old-fashioned "three-space" is a simpleton's illusion and an artificial shackle. Einstein himself gets along with it, in spite of the impression to the contrary. He merely points out that a fourth variable, time, is needed to locate an event as contrasted with an object. Rightly understood, there is no mystery here, no realm of the ultra-ultra accessible only to the mathematician in a trance. With no intention here of losing the reader in the Einstein Theory, we wish merely to point out that it would be a much more difficult undertaking to lose him physically in the mathematician's "four-space."

Mysticism in science, then, as we have been describing it, is either pretentious fraud, such as astrology, based upon borrowed prestige, or else it is a straining for weird and meaningless conclusions which spring from the accidental implications of unfortunate technical terms. Yet beyond the sham lies the reality of patient, respectable scientific thought to-day—and what do we find there? Why, a new sort of mysticism—a legitimate sort. We may describe it roughly as attempted explanation which awes and baffles because the universe itself happens to be awesome and baffling; and which apparently violates all common sense simply because the so-called "common sense" is not infallible. Mathematicians run squarely into this mysticism of things-as-they-are in grappling with the idea of infinity; astronomers meet it in the problem of the nature and bounds of space; and modern physics is shot with it from end to end.

By way of example, the algebra teacher's mild assertion that there is no smallest fraction bigger than zero often brings a protest from the student's outraged "common sense," though it is not hard, in this case, to still the uproar. But in the simple explanation, lighted as it is with imagination if it be explanation at all, a startling new idea must appear. As adults let us examine this idea.

Imagine a point, on the wall of a large room, which is nine tenths of the way from end A to end B. Then magnify the remaining one tenth so that it looks as long as the whole room now does, and take a second point nine tenths of the way to B again. Repeat the process over and over, each time magnifying the remaining tenth until it covers the whole original wall. Soon we transcend the world of measurement and reach a realm in which the physicist's atom has swelled to the vastness of the astronomer's uni-

verse. And yet the process continues—there is nothing in nature or logic to stop it. Inward and inward we march, to realms as real, perhaps, as those where man is dominant, and yet as far outside his instrumental reach as the blankness beyond the galaxies. Here lies the universe of the minute, as staggering, endless and full of potentialities as the great outside itself. Surely here is mysticism—legitimate mysticism—inherent in the nature of things and glimpsed through the magic keyhole of mathematics.

Illustrations swarm before us. Though the conclusions of "non-Euclidean geometry" are flawless mathematical deductions, they might well be considered unimportant because their intuitively preposterous premises rub the common-sense raw; yet some of these theorems seem to fit the startling universe of Einstein. The Einstein theory itself crashes through the structure of nineteenth century science founded by geniuses like Newton; but its conclusions are not to be brushed aside lightly because they flout this authority, nor because on first thought they look so highly unreasonable. The theory is intellectually respectable; make no mistake about that. But even here, in the popular explanations, at least, there is a taint of the more reprehensible type of scientific mysticism, of impressiveness gained through a confusion of terms, of statements which are false in the sense that they do not mean what they seem to mean. But all in all, when we examine the theory fairly we find, perhaps, that we have to go along with it, at least part way, while it tampers with time and space, does away with gravitation, and wipes out the ether through which light was said to travel. It is a highly bothersome complication of the old simple set-up; but nature seems to join Mr. Einstein in demanding that we give it heed.

Thus, in this modern age, mysticism once more raises its head. Snatched out of the murk of superstition by deeper and more accurate thinking, it turns calmly on its rescuer and lo, that saving science itself goes mystic. For it can not escape the universe around it—a universe of living things which sprang somehow from unfathomed beginnings; of forces, such as magnetism and gravitation and electricity, which can be labeled but not really known; of uncanny processes by which the potent magic of thought, stemming strangely from the sodden gray mass of the brain, creates new forms, starts new sequences, sweeps inward to the atom and outward to the galaxies of space. This it sees, and this it reckons with. Never again, perhaps, will chastened science expound the facts of the case with the smugness of old. Like the veriest bumpkin, it now senses the mystery inherent in the nature of things; with the humblest of men it tastes the brew made of wonder, bafflement and awe-struck recognition of all that is yet unexplained.

HUXLEY'S "EVIL" INFLUENCE

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TEN years ago self-appointed critics of Thomas Henry Huxley expressed the opinion that "the evil that a man of Huxley's calibre left to live after him will never be measured."[1] After reading such an estimate the author undertook to "measure" Huxley's "evil" influence on his many friends and enemies. The results of his research are embodied in the present paper.

In order to show the influence which Huxley exercised among his students, a few representative tributes will be quoted. However, it is to be noted that most of these represent the opinions of students whom he encouraged to continue in some branch of science and who later became known in their field. The tributes of that great body of unknown students have never been heard, but we may well believe that the sentiments which they would express would sound no discord with the major chord which we shall strike.

That it was not the laboratory system alone that made Huxley a great teacher is shown by the appreciative words of Professor W. J. Solas, who was his student before the advent of the laboratory teaching:

> It was never my privilege to know Huxley as a friend; he was my teacher, that was all; with reverence and affection I worshipped from afar. Now as I look back over a long life, I feel, while recognizing how great is my debt to my many distinguished teachers, that I owe to him more, both morally and intellectually, than to any other I can name.[2]

Henry Fairfield Osborn also seems to have been influenced more by Huxley's lectures than by his laboratory system, since, as he tells us, Huxley came through the laboratory not more than once a week. "Breadth and depth, culture from every source, lack of dogmatism, faith in the educational value of science without prejudice to the classics, these," Osborn felt, "were the keynotes of Huxley's influence as a teacher and writer."[3] In appreciation of this influence he dedicated his work on "The Age of Mammals" "to the memory of Balfour[4] and of Huxley, my chief teacher in comparative anatomy."[5] While at Columbia University Osborn used his "old master, Huxley" as a center for some remarks concerning a liberal education.[6]

Professor S. H. Vines, who introduced the Huxleyan system to Cambridge, received his training both as a student and demonstrator under Huxley. And according to his own testimony, "it was altogether a memorable experience, an invaluable apprenticeship in the art of teaching science."[7] Another of Huxley's demonstrators, T. Jeffery Parker, could not decide "whether a professor is usually a hero to his demonstrator," but he did know that he had "never ceased to be impressed with the manliness and sincerity of his character, his complete honesty of purpose, his high moral standard, his scorn of everything mean or shifty, his firm determination to

[1] J. H. Massingham and Hugh Massingham, ed., "The Great Victorians," pp. 227–238. New York: Doubleday, Doran and Company, Inc., 1932.

[2] W. J. Solas, *Nature*, 115: 748, May 9, 1925.

[3] Henry Fairfield Osborn, *Nature*, 115: 726, May 9, 1925.

[4] *Cf.* p. 4.

[5] Henry Fairfield Osborn, "Impressions of Great Naturalists," p. 71. New York: Charles Scribner's Sons, 1924.

[6] Henry Fairfield Osborn, "Huxley and Education," New York: Charles Scribner's Sons, 1910.

[7] S. H. Vines, *Nature*, 115: 715, May 9, 1925.

speak what he held to be truth at whatever cost of popularity."[8]

In addition to those previously mentioned, many other representative biologists were directly trained by Huxley. Among these we may mention Saville Kent, C. Lloyd Morgan, George B. Howes, W. Newton Parker,[9] Patrick Geddes, Angelo Heilprin and Angelo Andres.[10] These serve to show Huxley's ability not only to single men out but also to inspire them to investigate the problems which were pressing for solution. Moreover, since the majority of them became professors of biology, they have spread Huxley's influence as a teacher over the globe. One of them, Professor Howes, continued Huxley's work as professor of biology in the Royal College of Science.

It is a curious coincidence that men who frankly and freely express their indebtedness to Huxley became professors in the biological sciences at both of the old English universities. This fact, as well as the offer to Huxley himself of the Linacre professorship of physiology at Oxford on the death of Professor Rolleston,[11] well illustrates the change which had come over the universities even in Huxley's lifetime. Both Michael Foster and E. Ray Lankester were demonstrators for Huxley during the introduction of the laboratory system at South Kensington. Foster later went to Cambridge and Lankester to Oxford.

During the first Huxley lecture at the Charing Cross Hospital Medical School, the school where Huxley received his medical training, Sir Michael Foster said:

> If I venture to say that the little which he who is now speaking to you has been able to do is chiefly the result of Huxley's influence and help, it is because that only illustrates what he was doing at many times and in many ways. . . . His indirect influence was perhaps greater even than his direct.[12]

Huxley always felt that he had discovered Foster, and it was Foster who discovered Francis Balfour,[13] the young investigator whom we have already mentioned in connection with the joint dedication of Osborn's work on "The Age of Mammals." At the time of Balfour's tragic and untimely death in the year in which Darwin died, Huxley wrote:

> Heavy blows have fallen upon me this year in losing Darwin and Balfour, the best of the old and the best of the young. I am beginning to feel older than my age myself, and if Balfour had lived I should have cleared out of the way as soon as possible, feeling that the future of Zoological Science in this country was very safe in his hands.[14]

It was the elder Lankester who extended the original Huxleyan plan of beginning with the simple forms in biology and progressing to the more complex types. His son, E. Ray Lankester, spread the system to Oxford. He tells us that ever since he was a little boy Huxley had been his "ideal and hero." After Huxley's death he wrote:

> There has been no woman or man whom I have met on my journey through life, whom I have loved and regarded as I have him, and I feel that the world has shrunk and become a poor thing, now that his splendid spirit and delightful presence are gone from it.[15]

Even those from whom Huxley was at times estranged because of a fundamental difference in view-point are able to express appreciation for his teaching. St. George Mivart, the biologist, who accepted the Roman Catholic faith and,

8 Quoted from the reprint of Parker's Recollections to be found in Leonard Huxley, "Life and Letters of Thomas Henry Huxley," Vol. II, pp. 447–448. New York: D. Appleton and Company, 1901.

9 For the first four names, *cf.* Henry Fairfield Osborn, "Impressions of Great Naturalists," p. 70. New York: Charles Scribner's Sons, 1924.

10 For the last three names, *cf.* Patrick Geddes, *Nature*, 115: 740–743, May 9, 1925.

11 *Cf.* Leonard Huxley, *op. cit.*, Vol. II, p. 32.

12 Michael Foster, "Recent Advances in Science, and Their Bearings on Medicine and Surgery," *Smithsonian Report*, p. 363, 1896.

13 Leonard Huxley, *op. cit.*, Vol. II, p. 420.

14 *Ibid.*, p. 41.

15 *Ibid.*, p. 447.

after trying to reconcile evolution with it by a theory of derivative creation, was finally excommunicated, says of Huxley:

> It is almost needless to say that his teaching, both its manner and method, made a profound impression on me.[16]

Mivart had studied biology before he came to Huxley. He was therefore permitted to attend lectures as "an honorary student." However, in his Reminiscences he writes:

> As to science, I learnt more from him in two years than I had acquired in my previous decade of biological study.[17]

So he later sent his son to Huxley that he too might profit by such instruction.

Thus far, we have drawn our tributes largely from those who were primarily interested in biology. But Huxley's influence is attested also by students whose major interests were not in the field of science. As a representative of this class we may quote the impression which Reverend E. F. Russell, curate of a London parish, gives of Huxley:

> When, like Marcus Aurelius, in the evening of my life I look back upon past years and count up the names and benefactions of those to whom I owe so much, I find myself dwelling with especial gratitude upon the name of Thomas Henry Huxley, what he was and what he did; for from him I learned, so far as I was capable of learning, not only the principles of biology, and of the scientific method, but also, from his example, such high qualities as the habit of observation, accurate and intense, of patience and thoroughness in all we undertook, and—I would add—of courtesy to strangers.[18]

The foregoing list of students and laboratory associates is not intended to be exhaustive but only representative. It is impossible to give even a brief word of appreciation from all of Huxley's students who have expressed them. Moreover, we must ignore possible influences on such men as F. O. Bower and D. H. Scott, Marshall Ward and Alexander mac Nab, Burdon-Sanderson and H. Newell Martin.[19] However, since Huxley's influence was exerted not only through his students and those who assisted him in their guidance, but also through his many friends and correspondents, this paper would be incomplete without a word concerning the closest of these.

Huxley's friends and correspondents included some of the greatest thinkers of the nineteenth century. With some of these he formed life-long friendships in which the influence was reciprocal. The influence of Charles Darwin on him is too well known to require further comment, but it is not unlikely that Huxley also exerted an influence on Darwin. That Darwin valued his opinion is shown by the fact that Huxley was one of three judges, Sir Charles Lyell and Sir Joseph Hooker being the other two, upon whose decision as to the merits of the "Origin of Species" he determined to abide.[20] After his favorable verdict, Huxley became the "general agent" and "bull dog" for Darwin, and was easily the most aggressive of the judicial trio in imparting the essentially creative thought of the book to the world. That Darwin valued the generalship of Huxley is shown in an appreciative letter which he wrote to him before the tide had turned:

> The pendulum is now swinging against our side, but I feel positive it will soon swing the other way; and no mortal man will do half as much as you in giving it a start in the right direction, as you did at the first commencement.[21]

The pendulum did "swing the other way," as almost any schoolboy is now aware. That it did is due not only to Darwin and Huxley, but also to Sir Joseph Hooker, Alfred Russell Wallace and Herbert Spencer. Of this latter

16 St. George Mivart, *The Nineteenth Century*, 42: 988, December, 1897.

17 *Ibid.*, p. 991.

18 E. F. Russell, *Nature*, 115: 752, May 9, 1925.

19 These men served either as students or assistants under Huxley at different times. *Cf.* F. O. Bower, *Nature*, 115: 712–714, May 9, 1925.

20 Francis Darwin, "The Life and Letters of Charles Darwin." Vol. I, pp. 529–530. New York: D. Appleton and Company, 1911.

21 Francis Darwin, *op. cit.*, Vol. II, p. 328.

trio, Hooker was probably closest to Huxley. For over forty years these two friends worked together with never a misunderstanding. Time after time each sought and gave advice. Almost a hundred letters from Huxley to Hooker have been collected by the former's son.[22] That Hooker was not influenced would be inconceivable. If space permitted many evidences of this influence could be cited, but we must content ourselves with just one instance. Even after his first interview with Huxley, Hooker felt that with reference to the Salpae, a much misunderstood group of marine Hydrozoa, Huxley's "observations on their life-history, habits and affinities were on almost all points a revelation"[23] to him.

Although Huxley and Wallace met only on rare occasions and corresponded even less frequently, Wallace sums up a lifelong impression of Huxley in one sentence which we shall quote as representative of his feeling:

> I owe him thanks for much kindness and for assistance always cordially given, and although we had many differences of opinion, I never received from him a harsh or unkind word.[24]

While Spencer quarreled with Huxley, as indeed he did with many of his friends at one time or another,[25] he regarded their friendship as "an important factor" in his life.[26] The proofs of the "First Principles" were submitted to Huxley for his criticism.[27] Spencer felt that Huxley was "too yielding" in the sense that "if he is asked to undertake anything, either for the benefit of an individual or with a view to public benefit, he has difficulty in saying no."[28] But Spencer concludes that he should not "comment on this undue yieldingness and undue devotion to work which follows it" because he often betrayed Huxley into them by seeking his criticisms.[29]

However, Spencer probably relied more on the judgment of John Tyndall than he did on Huxley's criticisms. The final drafts of most of his writings seem to have been submitted to Tyndall for his approval.[30] For forty years the emotional Irishman and the reserved Englishman indulged in their intellectual companionship from afar. And this absence of frequent personal contact probably explains the length of the friendship. But the friendship of Tyndall and Huxley was even of longer duration than that of Tyndall and Spencer, since indeed it was Huxley who introduced Tyndall to Spencer.[31] Moreover, it was more of an intimate companionship than that of Spencer with Tyndall. Although Huxley could not claim Tyndall's birthyear as his own, as Spencer could, the two had many things in common. They were almost as brothers, and were often confused in the popular mind. Thus, although Huxley had been married for over twenty years in the year of his visit to America, the newspapers reported him as on his honeymoon with a titled bride. The fact was that Tyndall had married the daughter of an English Lord in this same year. Some years later Huxley wrote to Tyndall, informing him that he had "given up the struggle against the popular belief that you and I constitute a firm."[32] Throughout their lives the English biologist and the Irish physicist worked together for the recognition of science.

22 These are chronologically indexed in Leonard Huxley, *op. cit.*, Vol. II, pp. 518–520.

23 Leonard Huxley, *op. cit.*, Vol. I, p. 232.

24 Leonard Huxley, *op. cit.*, Vol. II, p. 432.

25 Maynard Shipley, *Open Court*, 34: 252, April, 1920.

26 Herbert Spencer, "An Autobiography," Vol. I, p. 466. New York: D. Appleton and Company, 1904.

27 Herbert Spencer, *op. cit.*, Vol. II, pp. 553–556.

28 Herbert Spencer, *op. cit.*, Vol. I, pp. 467–468.

29 *Ibid.*, p. 468.

30 Maynard Shipley, *op. cit.*, p. 253.

31 Herbert Spencer, *op. cit.*, Vol. I, p. 485.

32 Leonard Huxley, *op. cit.*, Vol. II, p. 274.

In 1864 Huxley felt that he and his friends were gradually drifting apart because of the stress of circumstances, so he proposed to Hooker that some kind of a regular meeting be established. Whereupon eight friends resolved to dine together once each month. These included an old quartet whom we have met: Huxley, the zoologist and later dean of the Royal College of Science; Hooker, the botanist and later director of Kew Gardens; Tyndall, the physicist and later superintendent of the Royal Institution; and Spencer, the philosopher and later the author of the "Synthetic Philosophy." The new quartet we must introduce: Edward Frankland, the chemist and later professor of chemistry at the Royal College of Science; George Busk, the anatomist and later president of the College of Surgeons; Thomas Hirst, the mathematician and later director of naval studies at the Royal Naval College, Greenwich; John Lubbock, the archeologist and later the author of "Prehistoric Times." At the second meeting of the club William Spottiswoode, "who carried on the business of the Queen's printer," became the ninth member of the group.[33] No more members were ever added because it was agreed that the name of any new member suggested must contain "all the consonants absent from the names of the old ones." Thus, "the lack of Slavonic friends . . . put an end to the possibility of increase."[34] For a name the group "accepted the happy suggestion of our mathematicians," says Huxley, "to call it the X club; and the proposal of some genius among us, that we should have no rules, save the unwritten law not to have any, was carried by acclamation."[35]

We have taken the time to give an outline of the X-Club not so much because of the influence of the club, although this was considerable, as to show the influence of Huxley on his friends. Such a group gave him a training quarter, so to speak, from which officers for the scientific cause would be drawn. As teachers their students would be taught to acquire "right ideas." This was the influence which Huxley indirectly exerted on a group, unique in the intellectual eminence of its members. All except Spencer were fellows of the Royal Society; three became presidents of the Royal Society; five received the Royal Medal; three were recipients of the Copley Medal; six were elected to the presidency of the British Association for the Advancement of Science. Once each month these eminent representatives of eight branches of science and its philosophy dined together; often they entertained eminent guests, including Darwin, Clifford, Strachey, Bain, Morley, Galton, Agassiz, Youmans, Gilman, Marsh and Helmholtz; during the summer week-end excursions of the X's and their yv's would widen the community of interests. For nineteen years these friends were able to enjoy their reciprocal influences before death broke the circle of friendship. And before nine more years had passed three of the links were missing and the chain so weakened that it was discarded.

However, Huxley's influence was exerted through other than scientific channels. He visited Benjamin Jowett, Master of Balliol, at least once each year. Dean Stanley and Charles Kingsley were two of his most sincere friends. His letters to the latter are some of the most revealing of his utterances. He even numbered the poets among his friends. Alfred Lord Tennyson, whom he met at various times at the Metaphysical Society, described him as "chivalrous, wide, and earnest, so that one could not but enjoy talking with him."[36]

[33] This enumeration is based upon that given in Leonard Huxley, *op. cit.*, Vol. I, pp. 277–278.

[34] Thomas Henry Huxley, *The Nineteenth Century*, 35: 10, January, 1894.

[35] *Loc. cit.*

[36] Hallam Tennyson, "Alfred Lord Tennyson," A Memoir, Vol. II, p. 110. New York: The Macmillan Company, 1898.

With all his friends, Huxley also had his enemies. Richard Owen he had dethroned from his position of authority in anatomy; the Lord delivered Samuel Wilberforce into his hands at Oxford; he had made short work of Gladstone's rhetoric. Huxley places this triumvirate in the same class, "a very curious type of humanity, with many excellent and even great qualities and one fatal defect —utter untrustworthiness."[37] But it was this defect against which Huxley's passion for truth revolted. No compromise was possible.

If Huxley had his enemies at home, he also had his friends abroad. In America President Daniel Coit Gilman valued his advice with respect to the incumbent for the first chair of biology at Johns Hopkins University. In Germany Ernst Haeckel built upon his foundations. In Italy Dohrn was an appreciative correspondent. As representative of this group of foreign friends, we shall quote the tribute which Haeckel's countryman, R. Virchow, paid when he delivered the second Huxley lecture at the Charing Cross Hospital Medical School. On this occasion Professor Virchow said:

> In truth, the lessons that I received from him in his laboratory—a very modest one according to present conditions—and the introduction to his work which I owe him form one of the pleasantest and most lasting recollections of my visit to Kensington.[38]

The many tributes to Huxley which we have quoted in the preceding paragraphs tend to show the influence which he exerted through his many students, associates, friends and correspondents. His practices were imitated, his lectures and writings were quoted, and his life became a lesson which others studied, an example which they tried to follow. In the face of the statement of our critics, it is important to note that the tributes stress Huxley's moral influence as often as they do his intellectual. Thus, Parker was impressed with his "high moral standard"; Solas expresses his debt as both moral and intellectual; and many of the other tributes imply traits which are recognized as essential to any system of morality. But the reader can judge for himself whether the lives of these influential men who have expressed so great a debt to Huxley or the empty rhetoric of critics shall constitute the greater evidence of Huxley's real influence.

[37] Leonard Huxley, *op. cit.*, Vol. II, p. 362.

[38] R. Virchow, "Recent Advances in Science, and Their Bearing on Medicine and Surgery." *Smithsonian Report*, pp. 571–572, 1898.

BOOKS ON SCIENCE FOR LAYMEN

MEDICAL RESEARCH[1]

SOMETHING may happen in the ectoderm when it folds in to make the human brain so that the individual possessing that brain has such an abnormal amount of curiosity and intellectual ability that he becomes what we know as a "researcher." This unique and not too widely distributed capacity lays out the paths along which nearly all our human advances are made. In the last fifty or sixty years, research ability in the field of medicine has taken advantage of the discoveries of physical and biological sciences and has gone ahead at a preposterous rate, compared with such progress in the past.

To study this type of research ability, to review the qualities of the medical research worker, to bring out the relationships between the universities, the foundations and medical research, is the object of these lectures delivered by Dr. Gregg on the Terry Foundation at Yale University. Dr. Gregg has a uniquely urbane and brisk style of writing. He fills his pages with apt quotations drawn from his wide reading and experience, but fundamentally his lectures have that particular quality which is known as "horse sense." It is this that makes his book of substantial value.

Dr. Gregg has had the chance to see new plants develop for medical schools, and with new buildings and new administrative responsibilities research by some of the best workers rapidly diminish. He has come in contact throughout the world with that peculiarly important atmosphere that is created by a research group. He, too, realizes the inevitable wastage of experimental research. Tests and experiments cost money, and often the results are nil or practically nil. In this expensive field of research the universities and the foundations have done much together. I think that Dr. Gregg's emphasis on the importance of fellowships is correct. In the long run, research is a wager on the capacity of men to grow and to continue their interest and enthusiasm in discovering new things. The foundations have gone a long way to establish the spirit of research and to support men who seemed likely to be most successful. At times they have seen their money go into dry holes; dust pockets are found in medical research as well as in oil fields.

The aim of the foundations to emphasize more local and university support as the foundations move to other fields is well brought out by Dr. Gregg. The weaning process is in many ways the most important element in developing research. To wean a research worker from foundation aid because he himself has become unproductive, or to pass him over to some other established institution because of his achievement, is necessary if medical research is constantly to go forward. Nuclei of research are thus spread over the country and the world. New men and new areas of interest must constantly be found. It is here that the foundations have their most significant opportunity. Fundamentally research depends upon surplus time and in a teaching institution upon overstaffing with men capable of research and enthusiastic for it.

Dr. Gregg's book is a real contribution to the furtherance not only of medical research but of all other forms of research as well.

RAY LYMAN WILBUR

[1] *The Furtherance of Medical Research.* Alan Gregg. ix + 129 pp. $2.00. 1941. Yale University Press.

INFORMATION FOR THE AIR NAVIGATOR[1]

THIS book is unique in that it combines in one volume all the subjects of vital importance to the navigator in the air—navigational astronomy, maps and weather. In fact, it was prepared at the request of the Army Air Corps Flying Training Command, in pursuance of a plan for training in mathematics and the physical sciences that extends from high school through college. The committee that outlined the course for the Army Air Corps was appointed by Dr. Forest R. Moulton, and the author of this book was named a member of the committee.

Dr. Wylie is professor of astronomy in the University of Iowa, where his years of practical experience in teaching have given him an excellent background for the writing of such a book as this.

The first part, consisting of six chapters, treats of the celestial sphere and its fundamental circles; the earth, its motions and its atmosphere; the change of seasons and the calendar; the constellations and the navigation stars. Both northern and southern circumpolar star charts are included, besides twelve excellent star charts for 40 degrees north latitude. For our fliers in southern latitudes, it would have been helpful to have had charts for latitudes below the equator, since the constellations appear and "behave" so differently where Orion and others are "up-side-down."

The second part, consisting of three chapters, treats of meteorology—winds, weather, clouds and weather forecasting. Beautiful photographs of the various types of clouds and other atmospheric phenomena are shown.

The third part, also consisting of three chapters, treats of maps and map-making, longitude and time, and celestial navigation. In this section the text is supplemented by numerous helpful illustrations.

The fourth part, consisting of eight chapters, is really a survey course in general astronomy, and is not to be considered a "required" part of the course. Presumably it has been included for those pilots and navigators, who may not have had a regular course in astronomy, but who may become interested in knowing more about the sun, moon, planets, stars and galaxies.

There are several small mistakes which will doubtless be corrected in future printings. Perhaps the most serious is the statement on page 219 that "the *astronomical day* commences at noon of the civil day of the same date." The so-called "astronomical day" begins at midnight, and this has been true since January 1, 1925.

The book is most attractive, the more so on account of the abundant excellent illustrations. It is practical and well suited for its purpose.

CLYDE FISHER

[1] *Astronomy, Maps and Weather.* C. C. Wylie. Illustrated. x + 449 pp. 1942. Harper and Brothers.

STRATEGIC MATERIALS AND NATIONAL STRENGTH[1]

THE Federal Government itself has not done a great deal to enlighten the public as to the reasons for the curtailment of various supplies because of the war. Of the several books which have appeared from private sources in the last few months on the general subject of war-time shortages, "Strategic Materials and National Strength" by Harry N. Holmes, despite its heavy title, is one of the smallest. For the general layman it is one of the more satisfactory books of this group since it makes rather clear in abbreviated and non-technical form the reasons for the need of wartime rationing of household and family supplies, as well as for the strict allocation of the materials of war industry.

[1] *Strategic Materials and National Strength.* Harry N. Holmes. Illustrated. v + 106 pp. $1.75. November, 1942. Macmillan Company.

An impression of authority and accuracy surrounds the writing, for Dr. Holmes is professor of chemistry at Oberlin and is currently (1942) president of the American Chemical Society. The style of writing is terse; some might call it concise, others abrupt. The inside-covers of the volume have maps showing the chief foreign sources of strategic materials; otherwise the book is scantily illustrated.

In addition to listing strategic materials, and describing the changes in requirements since 1917, Dr. Holmes gives interesting chapters on the development of synthetic rubber and of new sources of natural rubber, on the "Metals of Mars," on foods, vitamins and clothing, and on many other materials which affect all of us. There is even one chapter on "Fortunate Abundance." It is a commentary on the rapidity of changing conditions that a book written in May, 1942, mentions the fuel oil shortage only in these terms: "Heavy loss of tankers and inadequate pipe lines combine to create a liquid fuel shortage in some eastern states" (p. 62).

An important purpose of the book is to present the need for guarding the future. Dr. Holmes believes that several things might, and should, be done to prevent the future repetition of the stringencies of the present. The principal task should be the creation of stock-piles of strategic materials as soon as the war is over. Perhaps "reservoirs" is a better word since the materials need not be static, though held in reserve for emergency use. Material reserves represent, in Dr. Holmes' opinion, such an important national strategic potential that he believes they might actually control the balance of power and, assuming a continuation of our American inclination toward peace, prevent the recurrence of war.

A. C. SWINNERTON

TURTLES OF THE UNITED STATES AND CANADA[1]

THE author has made this book an excellent natural history of the turtles of the United States and Canada for the many who have kept or do keep pet turtles in the bathtub, for the layman and the naturalist.

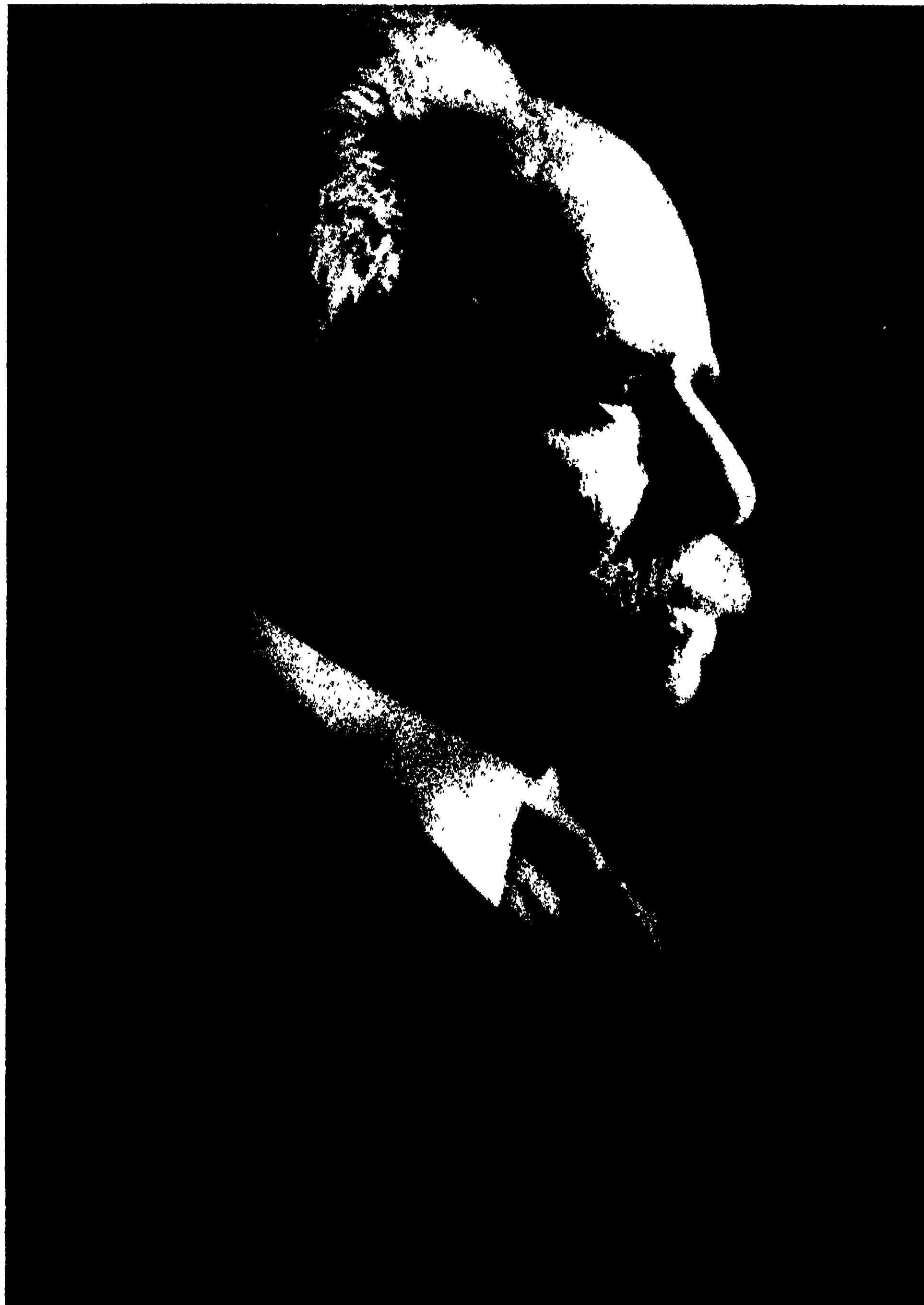
There are chapters dealing with the structure and relationship of a group of reptiles some 175 million years old and still thriving; others on food and feeding, enemies and defense, relation to man, and even on the care of baby turtles. Keys for the identification of the different groups and the species are so excellent that one deplores their absence in certain cases, and identification is made comparatively simple by the ninety-nine excellent photographs of living specimens, most of them taken by Mark Mooney, Jr.

After a discussion of turtles in general and their classification, each species is described with notes on habits and distribution. There is a good bibliography, and a list of all known species of the territory considered, with common and scientific names and a helpful index.

A most welcome book.

W. M. MANN

[1] *Turtles of the United States and Canada.* Clifford H. Pope. Illustrated. ix + 337 pp. $3.75. 1939. Alfred A. Knopf, Inc.



FRANZ BOAS, 1858–1942

THE PROGRESS OF SCIENCE

FRANZ BOAS, ANTHROPOLOGIST

WHEN Franz Boas died on December 21, 1942, he had long been a historic figure. To appraise his services to anthropology, then, seems comparatively easy. However, to render that contribution intelligible to a wider public is a formidable task. For Boas was not the bearer of any simple new message. Thousands, it is true, have been impressed by his championship of the "lower" races, and that fact renders his place secure in the intellectual history of the times. But though he discussed the issue in the light of modern knowledge, his position—long anticipated by earlier thinkers—constitutes, from a professional angle, a lesser claim to distinction. In short, his greatness rests not on some one startling discovery, but on the totality of his output, the total impact of his personality upon the young science to which he turned as his major interest in the eighties of the last century.

Let us visualize the scene when Boas visited the Central Eskimo on his first expedition in 1883. Notable, even epoch-making, work had already been achieved in the science of man, but it had been the work of others than trained anthropologists, for such were not in existence. Boucher de Perthes was an amateur prehistorian, Edward B. Tylor had taught himself anthropology after stimulation by another amateur prehistorian. Paul Broca, Rudolf Virchow, Adolf Bastian were all medical men; Lewis H. Morgan practiced law; F. W. Putnam was a geologist. Boas' contemporaries and immediate successors include zoologists like A. C. Haddon; physicians like Karl von den Steinen, F. von Luschan, Paul Rivet, W. H. R. Rivers; linguists like Wilhelm Schmidt; and he himself started as a geographer schooled in physics and mathematics. His doctoral dissertation at Kiel dealt with the color of sea water; among his earlier treatises are critiques of psychophysical methods, articles or reviews on icebergs, the topography of Hudson Bay, and the theory of map projection.

Considering Boas' beginnings and the activities of his compeers, nothing is more remarkable than his systematic self-professionalization when he had once decided on an anthropological career. For by this time techniques of diverse type had ripened or were ripening in the several branches of the science, and Boas heroically strove to master them all. In physical anthropology, we may conjecture, he acquired metric techniques from Virchow or his Berlin associates; but Boas soon recognized the importance of statistical methods for the investigation of variable phenomena and devoted years to the sedulous but critical study of Karl Pearson's treatises. Still more remarkable was his control of the philologist's tricks, including phonetics; whoever witnessed his discussions with professional linguists realized that they accepted him as in the fullest sense their peer. Ethnographic methods had not yet been fully established when Boas began his career, and he not only assimilated current approaches, but, more than most, helped towards their progressive refinement. With the intense specialization of the last decades Boas realized that no future investigator could hope for a uniform mastery of these several fields, but he fostered as much breadth in training as the varying capacities and temperaments of his pupils would bear.

This self-taught anthropologist, then, aimed at training professional research men. He schooled them in the spirit and the tools of inquiry, concerned solely with the advancement of knowledge. To convey cut-and-dried information was thoroughly distasteful to him. It is literally true that any of my better under-

graduate majors has a far better knowledge of general anthropology than I had when Boas approved my doctoral dissertation.

In his own opinion (letter to me, Dec. 30, 1937) Boas had contributed to "just three things,"—a reëxamination of the basis of physical anthropology; a presentation of languages on Steinthal's principles, *i.e.*, from their own, not an outsider's point of view; and "a more thorough empirical understanding of cultural life." This restrained self-appraisal hardly clarifies the extent of his influence. I shall venture to expand it by a psychological interpretation.

Boas' mind was in the highest degree critical, but not in the sense of sterility. Exacting as to evidence, and dealing with the most complex of phenomena, he abhorred facile generalizations and all-embracing systems. But this caution was not that of timidity, but of daring. The fact that a view was current among professionals, that it was approved by men whom he himself highly esteemed, counted for naught in the absence of supporting evidence. I have heard him reject a craniological interpretation of Virchow's, and he vigorously dissented from some of Tylor's conclusions. In short, Boas, like all great scientists, regarded things as they are, with complete freedom from the shackles of tradition. When blending inheritance still seemed an obvious conception, he reported segregation in the stature of half-breeds; when others still attached fetichistic value to the cephalic index, he showed that it was not a racial criterion of *primary* value; when virtually all ethnologists assumed as axiomatic the priority of matrilineal descent, he challenged the postulate as a result of his own findings.

To this freedom from authority Boas added an unusual capacity for detecting fruitful fields of inquiry, of giving to old problems an altogether new twist. It is merely necessary to compare his researches on primitive art with those of even his most gifted coëvals to appreciate this quality. His originality appeared likewise in his cavalier redefinition of such concepts as "totemism," which he recognized as the result of premature classification.

De mortuis nil nisi verum. To readers who had never met him, who had never viewed him either in historical perspective or in his total intellectual effort, his influence remained an enigma; one might well read a thousand pages of his output without finding more than a faithful, intelligent collector of raw detail. But even deeper knowledge might fail to attract, since ultimate judgments in science involve nearly as much individual taste as in the arts. Anyone held captive by the literary qualities of Tylor, let alone, J. G. Frazer, was bound to be repelled by the bleakness of Boas' diction; and even as to the more vital matter of organization his negligence of form sometimes transcended credibility, so that his books have been called negations of the idea of a book. Certainly his warmest admirers cannot be happy over a professedly general volume on *Primitive Art* nearly a third of which is devoted to the meticulous consideration of a single area. Boas must further leave unsatisfied those numerous minds who crave a scheme that shall enable them neatly to pigeonhole every item of experience.

But to congenial spirits this very renunciation, with its compensatory flashes of insight into an indefinite number of special problems, will loom as the very embodiment of bald grandeur. They will recall with pride that they had "seen Shelley plain," that they entered sympathetically into that ever searching, austere, yet original mind; and they will view his passing with sentiments not unlike those which Browning ascribes to the disciples of his Grammarian:

Lofty designs must close in like effects:
  Loftily lying,
Leave him—still loftier than the world suspects,
  Living and dying.

ROBERT H. LOWIE

DR. EDWIN H. ARMSTRONG, EDISON MEDALIST

IT has been announced that Dr. Edwin H. Armstrong, professor of electrical engineering, Columbia University, is to be awarded the Edison Medal by the American Institute of Electrical Engineers "for distinguished contributions to the art of electrical communication, notably the regenerative circuit, the superheterodyne circuit, and frequency modulation." The presentation ceremony took place on the evening of January 27, in the Engineering Auditorium, New York City.

This award was established by associates and friends of Thomas A. Edison to commemorate his achievements of half a century. It is the highest distinction conferred by the Institute. Dr. Armstrong is particularly worthy of this honor as he has made several major contributions to radio engineering during the past thirty years. The first came in 1914 with the publication in the December 12 issue of the *Electrical World*, of "Operating Features of the Audion" in which he presented the correct explanation of the functioning of the audion, or the electron tube as it is now called, as

a detector and as an amplifier with conclusive experimental proof. These results did much to stimulate the interest of amateurs and engineers in the use of the audion, for previous to this time the principles of operation were not generally understood and there was a wide divergence of opinion, even among those who were using the tubes.

With Armstrong's disclosure of the regenerative circuit, in 1915, what had been a keen interest became, in the 1920's, a consuming passion until most everyone was building radio receivers. Regeneration provided an inexpensive means of obtaining greatly increased sensitivity and as a by-product increased selectivity. It was directly responsible for the rapid growth in broadcasting during this decade.

While serving with the Signal Corps in France during the first World War, Major Armstrong developed the superheterodyne receiving system. This method makes it possible to design the intermediate stages of amplification for any desired frequency band, without reference to the frequency of the incoming signal; thus the intermediate amplifier may be permanently adjusted for the most favorable operating condition. It also provides a means of separating signals on adjacent channels which otherwise might interfere. This type of receiver is now almost universally used.

In 1920, Professor Armstrong developed the super-regenerative receiver which produced an extremely sensitive detector at a very low cost. It was used in the early two-way ultra-high frequency police systems and I understand that it is being used by the Germans in the present war.

The next problem to engage the attention of Professor Armstrong was that of improving the quality of broadcast service. Everyone is familiar with the distortions produced by static, other electrical sources, selective fading and the resulting garbled programs that too often mar reception. Professor Armstrong's proposal was to use frequency modulation to eliminate the foregoing sources of annoyance and at the same time to provide a fidelity and tonal range not possible with the narrow channels available in the broadcast band. While this problem has long been a challenge to radio engineers, Armstrong was first to make substantial progress towards its solution. In 1933, after years of research, he gave a demonstration in his laboratory, at Columbia University, to officials of the Radio Corporation and later submitted his system to them for field tests, but at the time they were more interested in television than frequency modulation. Two years later Armstrong presented a paper on frequency modulation and gave a successful demonstration before the Institute of Radio Engineers. The paper was published in the Proceedings for May, 1936. Despite all the promise of the system, industry showed no disposition to adopt it. However, Armstrong was so firmly convinced of the merit of frequency modulation that in 1937 he built a $300,000 station with his own money. Soon the Yankee Network became interested and was followed by F. M. Doolittle (WDRC), General Electric Company, Stromberg-Carlson, Radio Corporation, American Telephone and Telegraph Company and others. Much progress was being made when war was declared. There is no question but that the Armstrong system will be widely adopted as soon as peace comes, for it does eliminate static, selective fading and other distortion; fidelity and tonal range will be demanded by discriminating auditors.

Among the honors received by Professor Armstrong are the following: Medal of Honor of the Institute of Radio Engineers, 1917; Chevalier de la Legion of d'honneur, French Government, 1919; degree of Doctor of Science, Columbia University, 1929; the Egleston Medal,

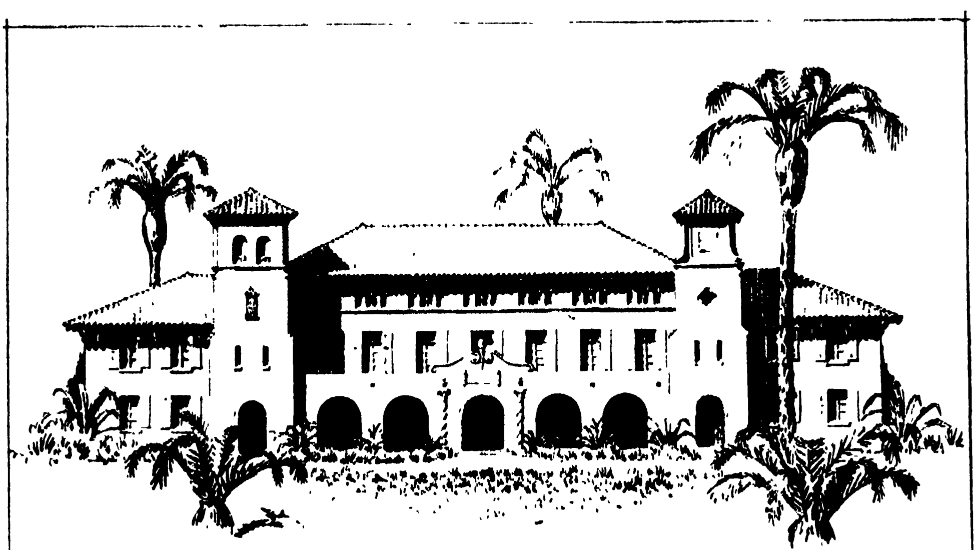
Columbia University, 1939; the Holley Medal, American Society of Mechanical Engineers, 1940; the Franklin Medal, Franklin Institute, 1941; the degree of Doctor of Science, Muhlenberg College, 1941; the John Scott Medal, awarded by the Directors of the City Trusts, Philadelphia, 1942. He also received one of the nineteen National Awards of "Modern Pioneer" by the National Association of Manufacturers, 1940.

H. M. TURNER

INTER-AMERICAN INSTITUTE OF AGRICULTURAL SCIENCES

FOR many years the need has been felt for a central organization to conduct long-range research projects in the agricultural sciences throughout the Western Hemisphere. The Eighth American Scientific Congress, held at Washington during May, 1940, recommended the establishment, in one of the Latin American countries, of an inter-American organization designed to carry out such research in agriculture. The Governing Board of the Pan American Union approved the By-laws of the Inter-American Institute of Agricultural Sciences on October 7, 1942, and recommended its establishment at Turrialba, Costa Rica, after an extensive study of plans for its organization and maintenance.

The immediate purpose of the Institute is the advancement of agriculture in the American nations through teaching, research, experimentation, extension activities, general education, and training in agriculture and related arts and sciences. The Board of Directors of the Institute is composed of representatives of the twenty-one American Republics on the Governing Board of the Pan American Union. A Technical Advisory Council, composed of one member from each nation, appointed by the respective governments, will consider questions of general policy and make recommendations concerning the advancement of the purposes for which the Institute is organized. There are two officers, the



THE INTER-AMERICAN INSTITUTE OF AGRICULTURAL SCIENCE
THE ARCHITECT'S DRAWING OF THE ADMINISTRATION BUILDING TO BE ERECTED IN TURRIALBA.

TURRIALBA VALLEY, SITE OF THE NEW INSTITUTE,
AS SEEN FROM THE SLOPES OF TURRIALBA VOLCANO AT AN ELEVATION OF APPROXIMATELY 5,000 FEET. THE TOWN NEAR THE CENTER IS TURRIALBA (ELEVATION 2,000 FEET). THE INSTITUTE WILL BE LOCATED AT A POINT TO THE LEFT OF THE CENTER OF THE PICTURE.

director, Dr. Earl N. Bressman, formerly director of the Division of Agriculture, Office of the Coordinator of Inter-American Affairs, and the secretary, José L. Colom, chief of the Division of Agriculture of the Pan American Union. The headquarters of the Institute are located in Washington, D. C., and other offices are to be maintained throughout the American Republics. Plans for the Institute also contemplate utilization of research facilities offered by several Latin American governments, such as the recently organized Experiment Station at Tingo María, Peru; the Agricultural Experiment Stations at Salta and Misiones, Argentina; the agricultural research center at Santiago de las Vegas near Habana, Cuba, and many others that have been offered as collaborating stations. Its activities, therefore, will not be confined to Costa Rica.

Turrialba, Costa Rica, was selected as an ideal location for the Inter-American Institute of Agricultural Sciences because, lying at an altitude of a little over two thousand feet, it offers within a distance of less than two hours by car or train an almost complete cross-section of Tropical American conditions. The program of the Institute will embrace the objectives outlined at the Eighth American Scientific Congress, which are: the promotion of a better balanced agricultural economy in the American Republics; the compilation of basic data on their agricultural problems; the development of a broader knowledge of plant and animal diseases and pests; and the training of future leaders in the agricultural field.

The Institute will play an important part in the war effort. As soon as it is completely organized, it will furnish ad-

vice to all official and other recognized agencies on the problems created by the war. It will strive to carry out the necessary research and will assume the responsibility of getting this work done. The Institute, as an applied research organization, will try to avoid duplication of services and activities of the various experiment and research agencies already working on the problems created by the war.

Building plans for the Institute in Turrialba have already been drafted and actual construction will start in the very near future. The decision to establish the Institute in Costa Rica was well-founded, as this country is one of the most progressive and democratic nations of this Hemisphere.

Organization of the Inter-American Institute of Agricultural Sciences is one of the most important projects in which the Pan American Union has participated. It is also one of the means best adapted to promoting closer cooperation among the American Republics.

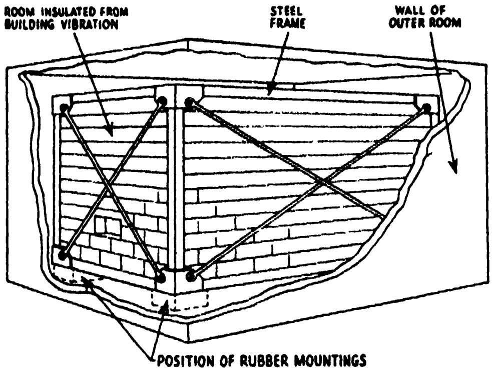
L. S. ROWE,
Director General

TECHNOLOGICAL INSTITUTE OF NORTHWESTERN UNIVERSITY

IN June Northwestern University dedicated, on the Evanston campus, a new building for its Technological Institute. The gift of Walter P. Murphy, inventor and manufacturer of railroad equipment, the institute has three main objectives: (1) to provide training in engineering for a select group of young men; (2) to provide industry with skilled workers and executives; and (3) to provide facilities for research in problems related to industry.

The keystone of the institute's program is the cooperative plan whereby students alternate three months of study in the classroom with an equal period of work in industry. The institute operates on a normal five-year curriculum. The student spends his first year on the campus in classroom study, thereafter

THE TECHNOLOGICAL INSTITUTE OF NORTHWESTERN UNIVERSITY
THE BUILDING CONTAINS MORE THAN 350 ROOMS AND HAS A FLOOR AREA OF 423,000 FEET, WHICH MAKES IT ONE OF THE LARGEST EDUCATIONAL BUILDINGS IN THE WORLD.



THE SOUND-PROOF ROOM
LOCATED IN THE PHYSICS DEPARTMENT OF THE INSTITUTE. THE SMALL WINDOW AT THE LEFT IN THE WALL OF THE ROOM IS TO BE USED FOR TAKING READINGS.

alternating each quarter between the classroom and a job in industry. Half of the class thus remains in college while the other half is at work. The next quarter these groups are shifted. This alternating schedule continues until the spring quarter of the final year, when the entire class is brought back to the campus.

A POWERFUL TESTING MACHINE
THE TRANSVERSE-UNIVERSAL MACHINE, WHICH IS CAPABLE OF APPLYING TRANSVERSE LOADS UP TO 1,000,000 POUNDS.

Seventy large firms, located in twelve different states, are now cooperating with the institute. The industrial concerns afford the students opportunity for direct experience and in return these firms are provided with young men who have been carefully selected and taught.

The institute has been operating on the cooperative plan since it opened in 1939. Ovid W. Eshbach, dean of the Technological Institute, recently said of this program: "The cooperative system brings the young man into contact with the realities of our industrial system. It shows him the significance of the facts and principles which he has acquired through books and in his classes. It makes him inquisitive. The alternation of theory and practice enhances the value of both, for after all they are not separate experiences but complementary processes in learning."

The new $5,000,000 building provides a modern, well-equipped plant in which to carry out the purposes of the institute. The structure has ten acres of floor space, but its immensity is partially concealed by skilful disposition of its masses. The general arrangement of the building is that of two letter E's laid back to back and joined by a central structure. The center is occupied by the main auditorium, lecture room, library, student lounge and main offices, while each of the six wings is devoted to one of the major divisions—the departments of physics and chemistry of the College of Liberal Arts, and the departments of civil, chemical, electrical and mechanical engineering of the institute. Two of the future objectives of the institute are the addition of departments of aeronautics, mineral industries, and architectural engineering and the establishment of a graduate school in engineering research.

Basically, the general design of the building is functional; yet enough of the Gothic is suggested in its silhouette and decorative details to make it harmonize with other buildings on the campus.

The exterior is of Lannon stone with Bedford stone trim. The varied color of the Lannon stone and the relatively small size of its pieces invest it with a warmth and intimacy which otherwise might be lacking. This feeling is intensified in the spacious entrance court, where the use of a flat, paving brick combined with stone creates a pattern that brings this extensive space down to human scale.

An example of the facilities which are available to students and to research workers is provided by the department of physics. This department has a special laboratory of explosion-proof construction in which it is possible to produce six gallons of liquid air and two-and-one-half gallons of liquid hydrogen an hour. Cold rooms, x-ray rooms, electrical laboratories, spectroscopic laboratories and heat and pyrometry laboratories comprise some of the important facilities for teaching and research. One of the features of the department is a sound-proof room which is being used for theoretical research. The room, which is inside another concrete room, is mounted on rubber. It weighs 50 tons and its walls are covered with 18 layers of muslin which absorb 98 per cent. of air-borne sound and mechanical vibrations from the outside.

ENTRANCE COURT OF THE INSTITUTE

THE ARCHITECTURE OF THE BUILDING IS MODERN GOTHIC, TO CONFORM WITH OTHER NEW BUILDINGS ON THE CAMPUS OF NORTHWESTERN UNIVERSITY.

In order to provide the environment and facilities through which students may develop their fullest possibilities and industry may profit from new knowledge and skill, the institute has been provided with more than $1,600,000 worth of new scientific equipment. Although some of the equipment is unique and affords opportunities for special types of investigation, the principal purpose has been to provide well-rounded facilities adapted to the needs of student training and general research.

No time has been lost in putting the

facilities of the institute to use. Many important research projects are now under way, and the essential tasks of furnishing technicians for the army and the navy and of training men and women for jobs in war industries are in full swing.

The present enrolment of the institute in its full-time program consists of about 850 students, of whom 340 are freshmen who entered last summer and fall. This freshman class was selected from approximately 750 applicants.

There are now 1,000 sailors enrolled in the Naval Radio Operators' School at Northwestern University, who do their class work in the Technological Institute. After a four-month course these men qualify as naval radio specialists. More than 100 men are also enrolled in the Army Signal Corps Officers' Training School, which has classes in the institute. Graduates of this course are commissioned in the Signal Corps, if they pass the physical examination.

One of the big problems of the war is that of getting trained personnel for skilled work in the defense industries. Through a series of constantly enlarged, evening, tuition-free courses the Technological Institute has provided more than 2,200 men and women with the background in industrial engineering they need to take over important jobs. A new program, not bearing academic credit, offers training in 40 subjects of engineering directly related to the war effort to more than 2,000 special students.

Dean Ovid W. Eshbach of the institute said recently that there are more than 5,000 men and women now taking work at the institute. Directly or indirectly all of these individuals are preparing for tasks which are vital to the war effort. But the leaders of the institute even now are looking forward to the future. The day will come when the last shot shall have been fired. It is then, as Secretary of Commerce Jesse Jones said at the dedication of the institute last June, "That those who have had the opportunity of studying at seats of learning will again play a leading part, for it will take as much skill and knowledge in our reconstruction program to turn our industrial and economic machinery back to its peace-time services as it has taken to convert this machinery to war service."

Since the foregoing was written Northwestern University has been notified of an additional gift of $20,000,000 from the estate of Walter P. Murphy, who died on December 16. This is the largest bequest ever made to higher education by a citizen of Chicago, and is probably the largest in the nation since 1924, when James B. Duke willed $40,000,000 to Trinity College (now Duke University).

Mr. Murphy specified that the fund should be used to develop, maintain and operate the Technological Institute of Northwestern University, which was founded in 1939 with a gift of $6,735,000 from the Walter P. Murphy Foundation. Beyond this restriction, he placed no limitations on the use of the bequest, leaving to the board of trustees of the university the final decision as to future management.

The donor expressed a desire that as much as possible of the principal should be held intact and used for endowment of the institute. At the same time he empowered the trustees to spend portions of the principal from time to time, and all or any part of the annual income, for additional buildings, equipment, professorships, scholarships, books, research and such other purposes as the trustees think necessary to the proper operation of the institute. He also specified that the institute, as a part of its operations, may give instruction in science to other than engineering students of the university.

The present bequest is Mr. Murphy's fourth benefaction to Northwestern. He made two gifts in 1923, one of $5,000 to the College of Liberal Arts, and one of

$10,000 to the School of Commerce. In 1939, through the Walter P. Murphy Foundation, he gave $6,735,000 to erect and equip on the Evanston campus the new building of the institute.

E. H. S.

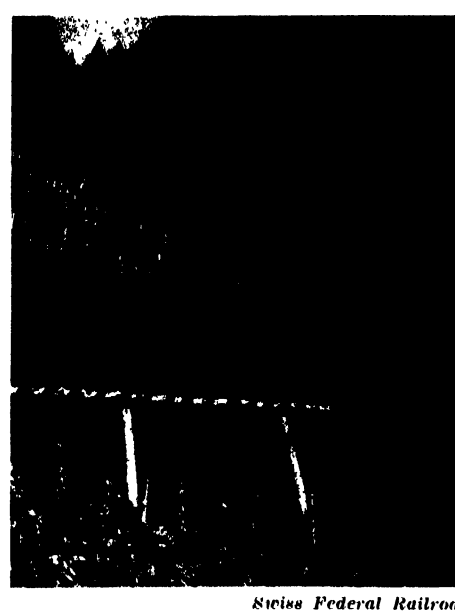
AVALANCHES IN THE ALPS

THERE are several kinds of avalanches: those known as dust avalanches, compact snow avalanches and ice avalanches. Of these three kinds dust avalanches are the most to be feared, for, while the others fall according to certain well-known rules and at particular times of the year, these avalanches are erratic in their movements, uncertain in the periods at which they descend, and most terrible in their results. Dust avalanches consist of cold, dry, powdery snow, which, falling on a slope of grass, slides off on the slightest provocation.

Often, if a bit of overhanging snow falls on the upper part of a hillside, or if an animal disturbs the newly fallen mass, or perhaps if a gust of wind suddenly detaches it from the surface on which it rests, the whole accumulation begins to move down, gently and quietly at first, and then with ever increasing power and a deafening roar, uprooting trees, carrying away chalets and whatever happens to be in its course, and leaping like a huge stream of spray-covered water from precipice to precipice, till it makes one final bound across the valley, the impetus of its course frequently carrying it up for some distance on the opposite slopes. The wind which accompanies such an avalanche is far more powerful than a raging hurricane, and it often levels trees and buildings, forces in windows and doors, and carries heavy objects an incredible distance.

In February, 1888, on the occasion of the fall of two great avalanches into Saas-Grund, most of the windows and doors in the village were forced in from the pressure of air. Tschudi states in his "Monde des Alpes" that such avalanches will sweep châlets and trees from the ground and carry them, whirling like straws in a storm, through the air, dropping them at a distance of upwards of 400 feet. Châlets filled with hay, and quite uninjured, have been found, it is said, some two hundred yards or more from the termination of the débris of an avalanche, having been blown across the valley by the blast of wind ahead of the avalanche.

In the year 1689, an enormous avalanche which, in the annals of the Grisons, is spoken of as the most fearful one on record in the Canton, came down from the heights above the village of Saas, in the Prättigau, and demolished 150 houses. Amongst the débris which had been swept by the avalanche to a considerable distance, a rescue party discovered a baby lying safe and sound in his cradle, while six eggs were found uninjured in a basket close at hand.

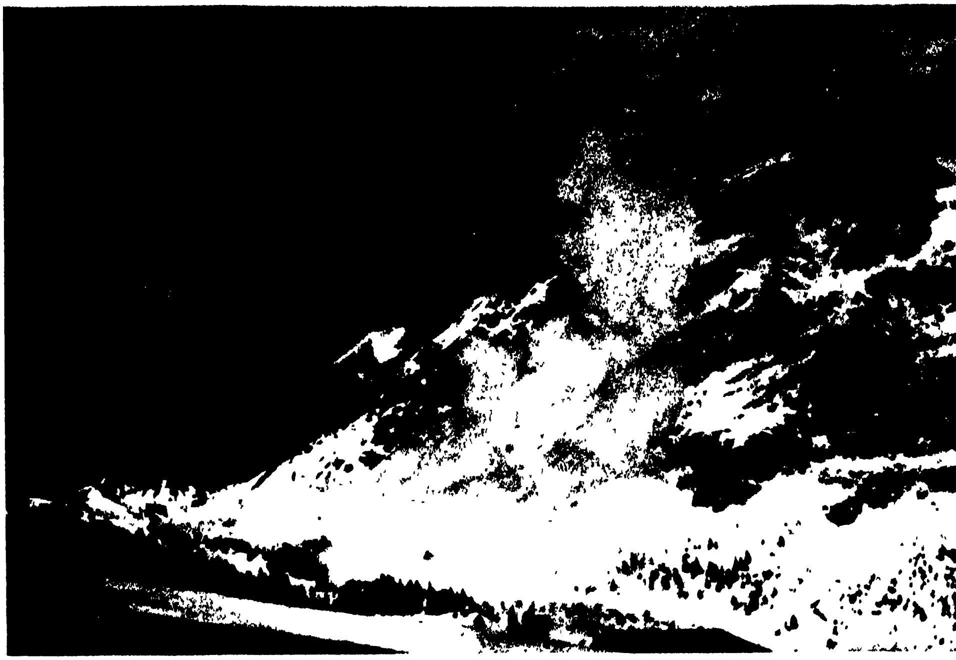


Swiss Federal Railroad

AVALANCHE PROTECTIVE MEASURES

TAKEN BY THE SWISS FEDERAL RAILROADS ON THE ST. GOTHARD LINE, BETWEEN ERSTFELD AND AMSTEG, NORTH OF THE GREAT TUNNEL.

SÉRACS IN THE VICINITY OF THE RHONE GLACIER IN SWITZERLAND



W. Lottenbach

THE DESCENT OF THE WETTERHORN AVALANCHE NEAR GRINDELWALD

IN THE BERNESE OBERLAND, SWITZERLAND. IT IS AN EXAMPLE OF THE DANGEROUS DUST TYPE.

K. Egli

SWISS SOLDIERS IN THE ALPS MEASURING AND STUDYING THE SNOW

TO DETERMINE WHETHER AND WHEN AN AVALANCHE IS DUE TO DESCEND TO THE VALLEY.

K. Egli

A SWISS ARMY SKIER

ON DUTY IN THE ALPS ABOUT TO SET OFF AN EXPLOSIVE TO BRING DOWN AN AVALANCHE BEFORE IT HAS HAD A CHANCE TO CAUSE DESTRUCTION.

Another sort of avalanche is formed by the sudden descent of an overhanging mass of snow. The slightest movement in the air will often suffice to break the cornice, and it straightway goes rolling down the slope. Such avalanches are not usually much to be feared, though a notable exception to this fact was furnished on the Bernhardino Pass when the mass of falling snow, overtaking the post in its passage, carried thirteen persons, and a number of sledges, over the precipice into the gorge beneath.

Dust avalanches of freshly fallen snow are very frequently met with in summer by climbers amongst the higher peaks of the Alps. It was an avalanche of this kind which caused the Matterhorn accident of 1887, in which a number of persons fell an estimated distance of six to eight hundred feet.

It is reported that in the winter of 1916–1917, during the World War, about ten thousand officers and soldiers were killed in the Tyrol in a single day by avalanches rushing down its steep mountain sides. Often conditions favorable for avalanches are recognized and the inhabitants avoid so far as possible the most dangerous places. For example, in early December, 1940, snow fell steadily, becoming deeper and deeper on perilous mountain slopes. The people living in the valleys below the heights passed anxious days. Finally, on December 13 and 14, avalanche after avalanche thundered down into the valleys, causing terrible destruction and claiming several human victims.

In order to reduce the serious losses of life from avalanches, the Swiss army, under General Guisan, began the scientific investigation of them in 1939. The studies were carried out on the mountains where avalanches occur. They included not only measurements of snow and determination of conditions favorable for avalanches, but also life-saving procedures in alpine conditions. One of the best methods of forestalling them is to start them with mine throwers before the snow has accumulated to dangerous proportions. By this method the great Dratscha snow field near Davos is being regularly reduced from which some years ago an avalanche descended and buried an entire train of the Rhaetian Railway.

F. DOSSENBACH

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MARCH, 1943

COLORATION OF ANIMALS AND THEIR ABILITY TO CHANGE THEIR TINTS

By Dr. G. H. PARKER

EMERITUS PROFESSOR OF ZOOLOGY, HARVARD UNIVERSITY

THE casual visitor to any of our larger zoological museums ordinarily carries away with him the impression that tropical animals, especially birds and butterflies, are possessed of what may be called a riot of color. The whole spectral range, blue, green, yellow, orange, and red, singly or more often in combination, is represented in these inhabitants of the tropics with such bewildering diversity and often in such brilliancy that their possessors may be said to be veritable living jewels. Our visitor, if he be at all observant, may also have noticed that the animals from the temperate regions are commonly of sober tints, for the most part dun-colored, and that those from the polar areas are in many instances white. Of what uses these various color schemes are to their possessors, how they may be subjected to control by the animals in which they occur, and by what steps they have arisen are questions that have long puzzled the naturalist and that remain today only very imperfectly answered.

Some of the most striking of these color conditions were known to the ancients. Aristotle described with remarkable accuracy the changing tints of devilfishes and of chameleons and further pointed out their probable significance in the economy of such animals. His descriptions of these phenomena are so true to nature that he must have observed them on the living creatures in their native haunts. But the intensive study of these matters is limited to the last hundred years or so during which an enormous accumulation of new observations has been made and much speculation on the subject has been provoked. This has led to a great diversity of opinion with the result that on many questions sides have been taken and heated debates have ensued. Only a few decades ago no less distinguished a person than a former president of the United States and an equally well-known American artist crossed swords on certain animal-coloration issues which brought particular aspects of the subject into momentary prominence. After the heat of the battle had subsided in this Roosevelt-Thayer conflict it was evident to an impartial critic that, as in most such cases, both sides were partly in the wrong and partly in the right. Although interested and distinguished scholars of this subject the world over have taken part in such contests, nowhere else than in these United States has the once head of a government entered the arena. Possibly this is a measure of what real democracy is and indicates a degree of liberty enjoyed not only by citizens of such governments but by their chiefs, though denied to those who rule even the closely related bodies as, for instance, constitutional monarchies. Here at least

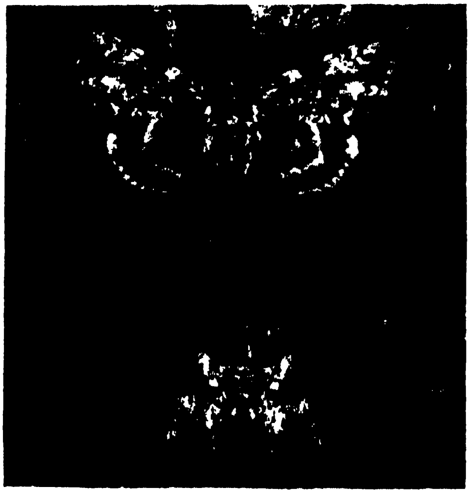

FIG. 1. UNDERWING MOTHS
PHOTOGRAPH OF MUSEUM SPECIMENS ON BARK: UPPER, WITH SPREAD WINGS; LOWER, WITH FOLDED WINGS.

the governmental heads, so far as I am aware, have never indulged in such activities, but have been so much engrossed with the doings of *Homo sapiens* that the color performance of their more lowly subjects have been allowed to pass unnoticed. But in whatever way the personnel of these discussions has been limited, the two extreme factions in such disputes, those who would belittle adaptive coloration or even deny its existence altogether and those who would see vital importance in every spot or mark on an animal's coat appear both to have missed the truth which seems very likely to lie in a middle ground of moderate interpretation maintained by the less excitable members of these forays.

When the substance of such discussions is impartially weighed there seems to be good reason for assuming that there really exist in nature many unquestionable instances in which coloration aids in concealment, in attracting attention, or in that type of imitation known as mimicry where one species of animal has stepped aside from its family form and coloration and has taken on the shape and markings of another species of quite different organization to the advantage of the imitator. It is also reasonably clear that many such well authenticated cases are extremely difficult to account for on the basis of the Lamarckian hypothesis of evolution, for in most instances among these animals the creature enters the world with its plan of coloration once and for all established and not subject to change by the later activities of the possessor, as muscles may be by use or disuse. This difficulty in explaining the evolution of most color patterns is not met with when Darwin's natural selection is invoked as the determining factor, for the animal with its given color coat is either a good fit or a poor one for its surroundings and hence is either more likely to survive, pair, and pass on its traits to its offspring or to die without leaving representatives. Hence the very presence of these types of coloration in nature is in itself a favorable omen for natural selection while it is on the whole a stumbling block to Lamarckism.

Animal Coloration in General

Before leaving these general aspects of animal coloration, however, it may be well to look for a moment at what have been regarded as good instances of the important types of this phenomenon. In a recent volume on this subject by the distinguished English zoologist, Hugh B. Cott, examples of animal coloration have been classed under three principal heads, concealing coloration, coloration for advertisement, and disguising coloration in which has been included those remarkable instances of specialization in form and tint known as mimicry.

Concealing coloration, to consider this class first, is well represented throughout the animal kingdom, but is especially often met with among insects. Although striking examples of this type of coloration are commonly assumed to be found only in distant and inaccessible parts of

the globe many of them occur near at hand, in fact at our very doorsteps. Of these the large noctuid moths of the genus Catocala are striking instances. The North American fauna is unusually rich in species of this genus known to every collector of our butterflies and moths. In some of these noctuids the spread of the wings may be three inches or more. In most species the fore or upper wings are dappled light and dark gray with some brown often interspersed and would be described on the whole as inconspicuously tinted (Fig. 1). The hind or under wings on the other hand have pronounced black marking on a mild background of red, pink, yellow, or white according to the species. In consequence of the striking coloration of their lower wings the members of this genus have been given the common name of underwing moths.

These moths can be found flying about in open woodlands even in the daytime and when on the wing are reasonably conspicuous. On settling down after flight they almost invariably come to rest on tree trunks and in so doing fold their colored underwings close to the body and cover themselves completely with the two approximated upper wings. The plan of coloration of the upper wings is so close to that of the trunks of the trees on which they rest that the closest scrutiny is often required to discover the moth as it clings to the bark (Fig. 1). In fact as this creature alights on a tree and covers itself with its upper wings it gives the impression of disappearing into the woody substance of its temporary resting place. Underwing moths when not in flight commonly rest on tree trunks in complete quiescence and are in consequence remarkably inconspicuous. It is well known to insect collectors that the darker species of Catocala frequent trees whose bark is dark such as oaks and the like and that the paler species are usually found on trees with paler bark like the beeches. Taking all in all it would be difficult to find a more perfect instance of concealing coloration than that shown by these moths, whose habits and color scheme aid so perfectly in their apparent obliteration.

A second example of concealing coloration is seen in the common crabspider, *Mitsumeria vatia*, of our countryside. This spider, the females of which may measure as much as half an inch in length (Fig. 2, A), is found very generally in the yellow flower clusters of the goldenrod. The tint of the spider agrees so exactly with that of the flowers that it is with the greatest difficulty that it can be seen nestled in among the yellow blooms. It is most easily discovered by shaking vigorously the flower clusters of the goldenrod over a shallow box whereupon the yellow crabspiders will be dislodged and easily caught. Under ordinary conditions these spiders rest hidden in the cluster of blooms (Fig. 2, B)

FIG. 2. CRABSPIDER
(A) FEMALE; (B) SPRAY OF GOLDENROD CARRYING TWO SPIDERS. ("THE SPIDER BOOK" BY J. H. COMSTOCK. 1912.)

where they remain unnoticed by the numerous insect visitants of the flower. The spider is thus enabled under favorable conditions to pounce unexpectedly upon its prey, seize the insect, and suck its juices. Though Mitsumena is not a large spider it is known to attack with success insects of the size of bumblebees. In this way the concealing coloration of the crabspider is an effective means in enabling this arachnid to obtain its supply of food. Mitsumena occurs not only on the yellow flower-clusters of the goldenrod, but also on the white masses of bloom of the wild carrot or Queen Anne's lace. When the crabspider is associated with the wild carrot it is white instead of being yellow in color. These color differences are said to be determined by the spider's environment.

The two examples of concealing coloration described in the preceding paragraphs, that of the underwing moth and of the crabspider, represent the two chief types of this kind of coloration. In the crabspider on the goldenrod the yellow color of the creature enables it to pounce successfully on its unsuspecting prey. This type of concealing coloration has therefore been called aggressive or offensive and is shared by not a few other animals. The mottled changeable color of the octopus or devilfish, as originally pointed out by Aristotle, enables this creature in its rocky habitat to creep up upon fishes unperceived and seize them as prey. The white coat of the polar bear in its background of snow aids this beast in its approach to and capture of its chief source of food, the seal, as this animal rests by its fishing hole in the ice. Many other instances of aggressive concealing coloration are known. These are, however, far outnumbered by the examples of the type of coloration for concealment represented by the underwing moth. In this instance the insect when at rest is overlooked by such foes as predatory birds and the like because of its resemblance to the bark of the tree on which it may have settled. Such a type of coloration has been called protective and in that sense is a defensive one. The group of insects abounds with innumerable examples of protective coloration, the green leaf-insects, the green and the brown walking-sticks, the multitude of green caterpillars with their rib-like stripes and hosts of other cases. Under this type falls the brown, mottled coloration of partridges and pheasants and the truly remarkable change of color in the pilage of the varying hare, dun-colored in summer and white in winter. Here also belongs the intense and varied coloration of tropical birds which though showy and brilliant beyond words in museum cases are lost to view in the tropical rain-forests where they flit about amid ever-changing intense shadows and sunlight and are indistinguishable from their surroundings in consequence of the welter of color change about them. Thus a host of instances of protective coloration with those of the aggressive type exemplify what has been designated as concealing coloration. These are Nature's efforts at camouflage so extensively practised now-a-days by man at war. We believe ourselves in this and other matters thoroughly up to date, but the palaeontologist can point to fossil walking-stick insects as far back in the history of the globe as the Jurassic Period, thus showing that these insects practised camouflage as long ago as 150 million years. Pride goeth before a fall.

The second general heading used by Cott in his discussion of animal chromatics is coloration for advertisement. A good example of this is the humblebee or bumblebee. Bumblebees are as much a part of the summer flower-garden as the flowers themselves. In their busy, ostentatious way these insects are the gossips of their native haunts and carry their stores of pollen from flower to flower, receiving a drop of nectar in return for what they bring. Though cumbersome, noisy, and fretfully active, they

are a part of their surroundings notwithstanding the conspicuousness of their color scheme. A garden without them would seem devoid of life, for they are fitted in size and color contrast with the world in which they live. Here they spend sunny days in full possession of what Nature gives them freely and man can not withhold. In general color they are dark, often really black and yet marked with conspicuous transverse bands or spots of yellow or even orange and red (Fig. 3). Kill me a red-hipped humblebee on the top of a thistle, says Shakespeare. Bumblebees are so common that we fail to note how conspicuous they are even amid the flood of colors of the summer garden. If the crabspider is tinted for concealment the bumblebee is colored for advertisement.

What the bumblebee advertises is its vicious sting. Sooner or later we learn to leave this insect to itself and more or less unconsciously set down its coloration as that of something to be avoided. The sting is an organ carried only by the queens and the workers, the two classes of females in the species. The males are without such organs yet notwithstanding this we avoid them as we do all other bumblebees without inquiring into their sex. Thus we court security even at the expense of knowledge.

The principle of advertising coloration illustrated by the bumblebee is believed to hold for the great majority of conspicuously colored animals. Creatures that in their natural haunts stand out as strikingly visible may well be suspected of harboring disagreeable and often dangerous traits. To this category belong the other stinging insects such as the common bees, and wasps and the brilliantly colored mutillas with their firy needles. Among the higher animals the skunk is believed to notify the inquisi-

American Museum of Natural History

FIG. 3. BUMBLEBEE AMONG APPLE BLOSSOMS

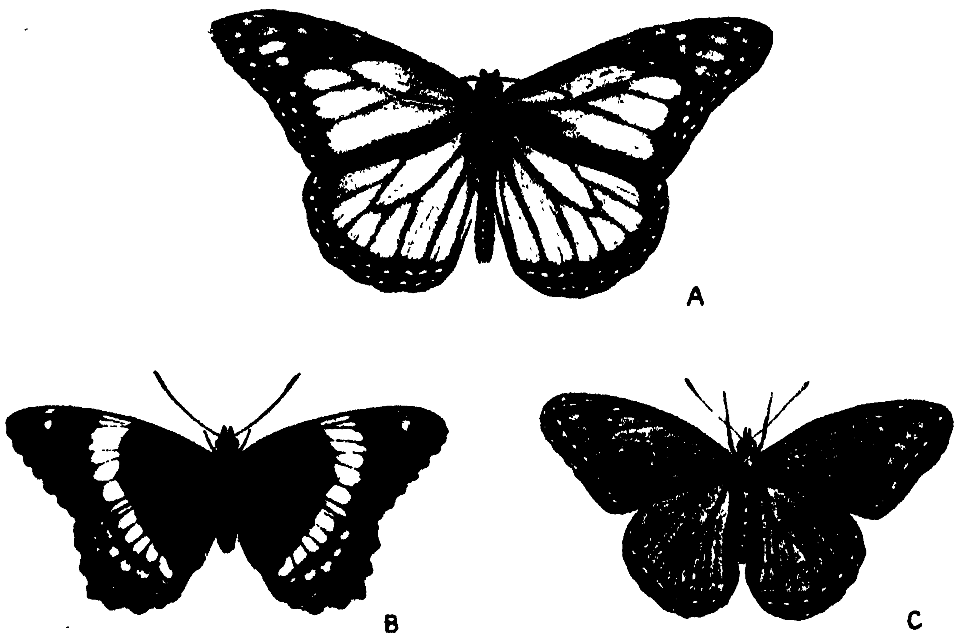

FIG. 4. MIMICRY OF THE MONARCH BUTTERFLY
(A) MONARCH; (B) BANDED PURPLE; (C) VICEROY.[1]

tive of its offensive traits by its highly contrasted coat. Such colorations are often described as warning.

The third and last general heading in animal coloration used by Cott is what he has designated disguising coloration and includes among other instances those of mimicry. This phenomenon is again best seen in the insects. In such instances a given species whose family coloration is of a definite type abandons this coloration and assumes that of another group of quite different organization. As already stated this change is believed to be to the advantage of the imitator. The animal imitated is commonly called the model and the imitator the mimic. An example of this kind is seen in two of our common butterflies, the monarch, *Danais plexippus*, and the viceroy, *Basilarchia archippus* (Fig. 4). The monarch (Fig. 4, A) is our largest butterfly and may in exceptional cases measure fully four inches across the wings. The body color of its wings is brown with dark veining and a fairly broad dark, almost black marginal band which is particularly wide at the outer angles of the forewings where there are numerous light spots. The monarch frequents open fields and is especially associated with milk-weed on which it lays its eggs. Hence it is often called the milk-weed butterfly. It is vigorous in flight and is noted for its extensive migrations. The viceroy butterfly (Fig. 4, C) is somewhat smaller than the monarch. Its wings spread at most three inches. The body color of the viceroy is brown, almost exactly that of the monarch. Its wings have a dark veining with marginal bands and pale spots in striking agreement with the corresponding parts in the larger insect. In fact

[1] (A) From "The Butterflies of the Eastern United States" by G. H. French. 1886; (B) From "Insects Injurious to Vegetation" by T. W. Harris. 1862; (C) From "A Manual of Zoology" by S. Tenney. 1872.

the two butterflies except for size are almost identical. The viceroy is also a butterfly of the open fields. Notwithstanding these numerous points of similarity the monarch belongs to a different subfamily, the Danainae, from the viceroy which is a member of the Nymphalinae. These two subfamilies differ structurally. Thus in the danaids the antennae are naked; in the nymphalids they carry scales.

When the other members of the two genera to which the monarch and the viceroy belong are compared a striking contrast is to be observed. The coloration of other danaids is brown and in very close agreement with that of the monarch. The near relatives of the viceroy on the other hand are dark in color and often of a purplish tone. Thus in the nymphalid known as the banded purple, *Basilarchia arthemis* (Fig. 4, B), the wings have a very dark ground tint with a concentric system of broad white bands and with rows of marginal dots and lunules some reddish and other blue thus giving it a purplish tone. Other members of the genus Basilarchia are in color much like the banded purple. None of them resemble the viceroy.

From these facts it is to be assumed that the monarch has remained true to its family coloration, but that the viceroy has departed from its traditional color scheme. In the combination of the monarch and the viceroy then the former must be the model and the latter the mimic.

In what respect does the viceroy profit by its change of coloration? The group of butterflies to which the monarch belongs is noted for their rank and disagreeable odor. Collectors of insects are familiar with this trait in all danaids. This feature may well be repellent to birds and other predacious animals. No such odor is associated with the viceroy which may, however, profit by its color resemblance to the monarch and be left untouched by the common foes of butterflies. Thus the viceroy is believed often to escape destruction which it might well otherwise meet. If monarch and viceroy are related as here outlined the geographical distribution of the two species ought to be such that the area occupied by the mimicing viceroy should be within that of the model monarch. If this were not so the mimic would be unprotected in its extraterritorial area. As a matter of fact in these two butterflies this condition is fully met. The monarch is found over the whole of temperate North America from the Atlantic seaboard to the Pacific coast and southward to the Gulf of Mexico. The viceroy on the other hand is limited to the eastern portion of this range and nowhere extends beyond it. Thus these two butterflies afford a good example of mimicry in their coloration and show in their areas of distribution a conformity to the theoretic requirements.

The three main classes of animal coloration as outlined by Cott have now been illustrated by one or two examples each and have received what may be described as a sympathetic presentation. What can be said by way of criticism of this whole treatment of animal coloration? The chief weakness of this view, inviting as it is in some respects, lies in the fact that it is almost purely hypothetic and lacks that kind of evidence which is ordinarily looked upon as conclusive. Such evidence must come from experimental tests. Are underwing moths really protected by resembling the bark of the trees on which they alight? Could not the crabspider if of another color than that of the flower head in which it lurks catch its prey with equal success? Such questions as these must be answered first before an unqualified assent can be given to the adaptive interpretation of animal coloration. Some experimental evidence on this general problem has as a matter of fact already been acquired, but it is scarcely more than a beginning. Sumner subjected

FIG. 5. CATFISH MELANOPHORES SHOWING COLOR RANGE: (A) FROM PALE TO COAL-BLACK; (B), (D), (F) LARGE MELANOPHORES WITH CONCENTRATED, INTERMEDIATE AND DISPERSED PIGMENT; (C), (E), (G) SMALL MELANOPHORES WITH CONCENTRATED, INTERMEDIATE AND DISPERSED PIGMENT.

numbers of pale and of dark mosquito fishes, Gambusia, to attacks from several predators, the Galapagos penguin, the night heron, and the blue-green sunfish. In each trial equal numbers of dark and of pale mosquito fishes were liberated in one test over a black background and in another over a pale gray one. A predatory bird or fish was then allowed to feed upon them. As a result of these tests it was found that the mosquito fishes which fitted the backgrounds were less numerously seized and eaten than those that were of contrasted tint. In a general summary of the whole set of experiments made by Cott it was shown that of 2,672 fishes offered as prey 1,150 were reckoned as casualties of which 395 (34 per cent) were of the less conspicuous individuals and 755 (66 per cent) of the more conspicuous ones. Plainly there was shown in these tests a real advantage to the possessor of the so-called protective coloration. It is experimental evidence of this kind obtained either from the laboratory or from the field that will settle many current problems of animal coloration and such settlement will be more conclusive than that based on wordy discussion.

Animals with Rapid Color Changes

Animals with the remarkable capacity of rapid color change have long been known and their significance for the general theory of adaptive coloration has been fully recognized. Beside a few sporadic instances of this kind of change among such creatures as the sea-urchins, the leeches, and the insects, the animals that show this remarkable capacity are found in three independent groups, the cephalopods such as the devilfishes and squids, the crustaceans including the shrimps, prawns, crabs and the like, and the cold-blooded vertebrates, the fishes, frogs, salamanders, and many of the reptiles especially the lizards. Among the vertebrates the fishes have received perhaps the most attention and these animals will serve as a basis for the following account.

The majority of fishes can be shown to exhibit more or less change of color. In tests of this kind some fishes like the squirrel fish of Bermuda will change from pale to dark or the reverse in a few seconds while others, such as the common New England catfish, will require from one to several days to make these altera-

tions (Fig. 5). Color changes are brought about by readjustments in the pigment content of the color-cells, or chromatophores, in the skins of these animals. The most usual kind of vertebrate chromatophore contains granules of black pigment and is known in consequence as a melanophore. In the pale condition of such a fish as the catfish the pigment is collected about the centers of the color-cells (Fig. 5, B); in the dark condition it is scattered throughout the bodies of the cells and their processes (Fig. 5, F). The shifting of the pigment back and forth within the color-cell is what changes the tint of the fish.

In addition to the melanophores many fishes possess true color-cells with characteristic pigments: xanthophores with yellow, erythrophores with red, and leucophores with white. In many fishes there are groups of crystalline plates which vary greatly in color and which are covered or exposed by the migration of the pigment in the surrounding melanophores. Such combined structures are called chromatosomes.

Depending upon their chromatophores different fishes exhibit different degrees of color activity. The common catfish possessing only melanophores has a limited color range from a pale greenish yellow to a coal-black (Fig. 5). In the killifish in addition to melanophores there are xanthophores, leucophores and green-blue chromatosomes. These fishes change not only from dark to pale (Fig. 6) but they may assume yellow, green, blue or even red tints. The red coloration is due to an enlargement of the integumentary blood vessels, a true blush. The color changes in tropical fishes are like those in the killifish except that they are much more exaggerated. In some of these fishes even the general pattern seems open to change, almost to obliteration, as in the Nassau grouper (Fig. 7). The southern flatfish, Paralichthys, will respond roughly to different checkerboard patterns by becoming more finely or coarsely spotted (Fig. 8) in accordance with its background. Such pattern changes, mostly due to melanophores, when coupled with true color changes give tropical fishes an almost limitless range of tints.

FIG. 6. KILLIFISH
UPPER, DARK PHASE; LOWER, PALE PHASE.

How these color changes in fishes are controlled has been a problem for a century past. In 1852 Brücke pointed out that when cutaneous nerves in the chameleon were cut, the areas of skin thus

FIG. 7. NASSAU GROUPER
(A) PALE PHASE; (B) DARK PHASE. ("CAMOUFLAGE IN NATURE" BY W. P. PYCRAFT. 1925.)

denervated darkened by the dispersion of their melanophore pigment. In 1858 Lister, then a young student of medicine, discovered that in the common frog the eyes were essential to color changes and declared in favor of a nervous interpretation of vertebrate chromatism. Pouchet, whose work on fishes (Fig. 9) confirmed that of Brücke on the chameleon and of Lister on the frog, showed that the part of the nervous organization concerned with color changes was the sympathetic or autonomic system, a view subsequently supported by von Frisch and many other workers. Thus the nervous interpretation of the phenomena of color change in vertebrates became paramount.

Meanwhile Hogben and Winton, who had been actively engaged in the study of the chromatism of the frog, were led to conclude from their experimental tests that in this animal nerves played a wholly insignificant part in color change if in fact they played any part at all. Evidence obtained from experiments on the frog's pituitary gland which is situated in the base of its brain led these investigators to declare that the dark color of this amphibian was due to a substance, a hormone, produced in the pituitary gland whence it was carried by the blood to the melanophores throughout the body. The pale color of this animal they believed to be due to the absence of this substance. Thus the occasion of the color changes in this amphibian was shifted from nerves to a blood-borne hormone. This substance, later called intermedine, thus became the all-important factor in the chromatism of the frog. From this and other work it was concluded that though the color changes in fishes and reptiles were dominated by nerves those in amphibians were essentially hormonal.

This novel and somewhat anomalous situation stimulated further work on the color changes in the lower vertebrates

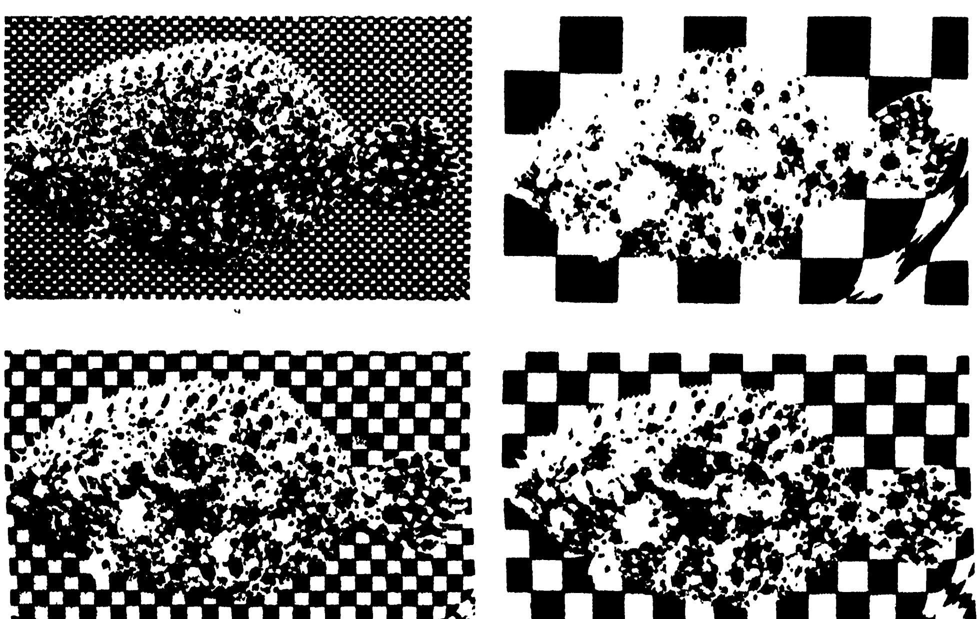

FIG. 8. THE SAME INDIVIDUAL FLATFISH
ON FOUR DIFFERENT CHECKERBOARD PATTERS. (S. O. MAST, BULL. U. S. BUR. FISH. 1916.)

particularly in the fishes. Much of what is new in this field can be illustrated by the color responses of the common New England catfish Ameiurus. As already stated this fish ranges in tint from a pale greenish yellow to a coal-black (Fig. 5, A). It possesses only melanophores. These are of two kinds large in the derma and small in the epidermis. In the pale phase the pigment in each color-cell is reduced to a dot large or small (Fig. 5, B and C); in the dark phase it is spread throughout the color-cells and their branches (Fig. 5, F and G).

To what extent are the color-changes in fishes like the catfish under the control of nerves and is there any evidence of hormone action in such creatures? In the catfish as in many other common fishes there is good evidence that the color changes are at least partly under nervous control. If, following the procedure originated by von Frisch, a particular spot in the medulla oblongata of the catfish is stimulated electrically, the whole fish will quickly blanch (Abramowitz, 1936). This response, however, does not include denervated areas. Hence it must be nerve activity that induces it, for where nerves are absent it fails to appear. Thus the concentration of melanophore pigment in the catfish must be occasioned by nerves. Responses of this kind have been observed many times in numerous fishes and have long been accepted as conclusive evidence for the presence of concentrating nerve-fibers in these animals. The opinion that this type of nerve-fiber is present in fishes and as a matter of fact also in certain lizards seems established beyond all doubt.

Whether there is an opposing type of nerve control for melanophores is not so easily demonstrated. From the time of Brücke it has been believed that the dark areas of skin due to the cutting of cutaneous nerves is the result of the paralysis of the concentrating fibers and their

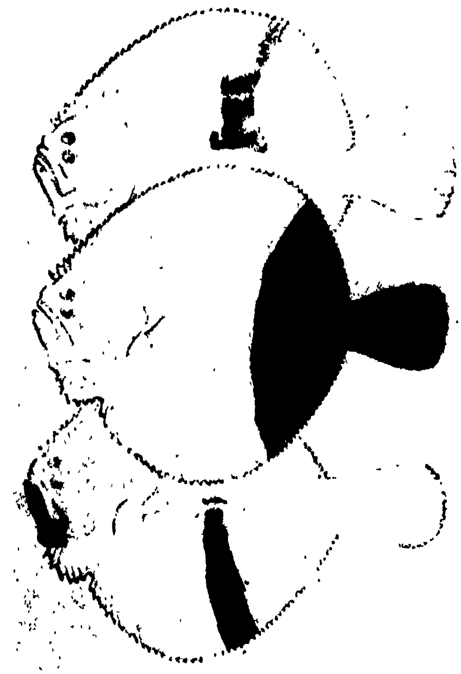

FIG. 9. TURBOTS
WITH DARKENED AREAS DUE TO DENERVATION.
(POUCHET, JOUR. ANAT. PHYSIOL. 1876.)

color mechanism. It is possible, however, to show the incorrectness of this view even on the catfish. If a bundle of nerves in the tail of a pale catfish is cut, a dark denervated caudal band will quickly appear. This band represents what the older workers regarded as the paralyzed region of the color system. After a day or two, however, such a band will blanch considerably and if now it is recut in a region slightly distal to the initiating cut, the band will again darken (Fig. 10). Such a redarkening could not occur if the band was actually paralyzed, for the band should then be inactive. This second darkening makes it clear that the color mechanism of the band is still functional and far from paralyzed. Hence the view that the caudal and other like bands are palayzed must be incorrect. The most probable explanation of this phenomenon is that the cut chro-

FIG. 10. TAIL-FIN OF CATFISH WITH CAUDAL BANDS. UPPER BAND PARTLY BLANCHED (COMPARE WITH OTHER PARTS OF TAIL, FULLY BLANCHED); LOWER BAND PARTLY BLANCHED AS UPPER BAND WAS AND THEN RECUT, IN CONSEQUENCE OF WHICH IT HAS DARKENED (COMPARE LOWER BAND WITH UPPER BAND).

matic nerve contains at least two sets of fibers one of which, the concentrating set, is open most easily to electric stimulation and the others, the dispersing set, is stimulated most easily by cutting. Such a view implies double innervation for catfish melanophores and puts them in the same category as the heart-muscle of the higher vertebrates where one set of nerve-fibers accelerates and the other retards this organ. It is interesting to observe in this connection that in the innervation of the melanophores of the perch and other fishes as worked out histologically by Ballowitz in 1893 not one but several nerve-fibers as a rule are distributed by numerous terminals to each color cell (Fig. 11). Of course one fiber might well be a concentrating element and another a dispersing one. Thus even the histological findings in this field are favorable to the idea of a double innervation. As a matter of fact double innervation of chromatophores was long ago suggested by Bert (1875) for these cells in the chameleon, but without supporting experimental evidence. This view of chromatophoral innervation at least in the common fishes seems now to be gaining more general credence (Waring, 1942) than when it was reaffirmed a decade or so ago (Parker, 1932).

From the evidence thus far presented it is clear that the catfish like other members of its group has a very complete nervous mechanism for the control of its melanophores. Nor is there any reason to believe that it needs more. It is, however, not without importance to raise the question whether this fish may not possess other means of controlling its melanophores than the two sets of nerve-fibers already described. If such another activator were present it might well be the secretion from the pituitary gland, intermedine. After the removal of this gland from a catfish the creature presents a remarkable limitation in its capacity for color change (Abramowitz, 1936). Although such a fish can become fully pale, it is unable to darken in normal dark surroundings to more than what would be called an intermediate stage (Fig. 5, A, D and E). Apparently this is the limit of efficiency for the dispersing nerve fibers, the one obvious darkening agent left. If into such a partly dark fish a quantity of intermedine is injected, the fish will darken fully. This test indicates that the complete darkening of a catfish is dependent upon intermedine which can also be shown to be capable in itself of carrying catfish from a completely pale to a completely dark state. Hence catfishes appear to have another darkening agent in addition to the dispersing nerve-fibers, namely the pituitary hormone, intermedine. They thus may be said to

possess in all three well established melanophore activators: for darkening, pituitary intermedine and dispersing nerve-fibers; and for blanching, concentrating nerve-fibers.

The catfish, from the standpoint of its kinds of melanophore control, presents an extremely interesting condition, for it possesses not only a nervous mechanism in its color system but also a hormonal one. This combination, which is found in a number of other common fishes, indicates a much closer relation between these two means of color control than that implied in the general statement that fishes and reptiles activate their color-cells by nerves and amphibians by hormones. How in fact are these two systems related?

The hormone intermedine is produced in the pituitary gland of the brain whence it is carried in the blood and lymph of the fish to the melanophores in the skin and pigment of which is thus stimulated to disperse. This is a very simple and direct way of applying an activating agent to its responding part. How do the two sets of chromatic nerve-fibers stimulate color-cells? These two sets of fibers belong to the autonomic nervous system and might well be supposed to act on the color-cells through the two activators so common in this system adrenaline and acetylcholine. Is there any evidence that these substances are associated with the catfish color system?

Appropriately made extracts of catfish skin can be examined for adrenaline by a biochemical test as shown in the responses of a Straub frog-heart preparation. Adrenaline is destroyed by heat. When unboiled and boiled extracts of catfish skin are applied separately to Straub frog-heart preparations, a vigorous response is elicited by the unboiled extract and a very faint reaction by the boiled one. As these tests are specific for adrenaline the excess of response to the unboiled over the boiled extract must be due to this agent. It is therefore clear that the unboiled skin extract must contain some adrenaline. Bray showed as early as 1918 that 0.2 cc. of adrenaline one part in a million of Ringer's solution would on injection blanch a whole catfish, an observation substantiated by many subsequent workers. Taking these several observations together it is beyond doubt that adrenaline is a constituent of the catfish skin and it is very probable that it is the agent which in conjunction with the concentration fibers induces the melanophores of this fish to concentrate their pigment.

In a similar way a biological test for

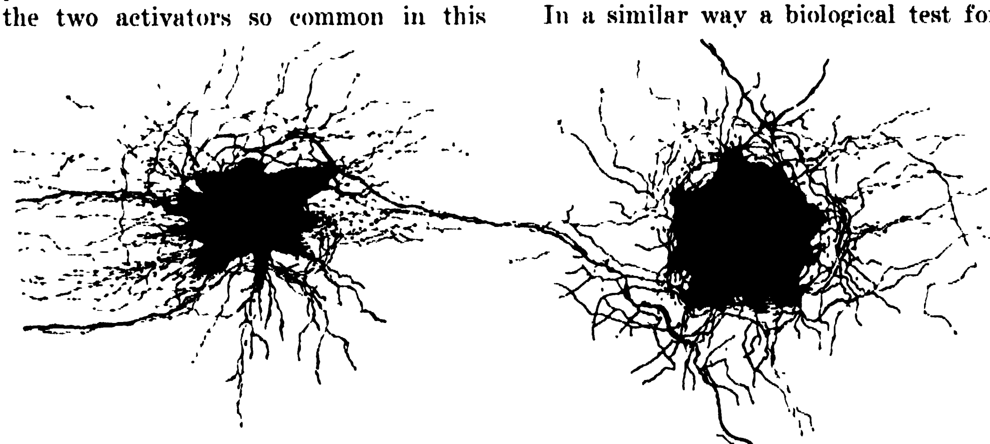

FIG. 11. INNERVATION OF TWO MELANOPHORES IN THE PERCH
(FROM BALLOWITZ, ZEIT. WISS. ZOOL. 1893.)

acetylcholine can be made use of in the responses of strips of leech-muscles to appropriate fish-skin extracts. This method moreover allows of quantitative results. By its use the amount of acetylcholine per gram of wet fish skin has been found to be 0.078 gamma or about one part of actetylcholine to 13 million parts of skin. It is not easy to appreciate the smallness of this quantity of acetylcholine. If we assume the distance from Boston to New York, some 230 miles, to represent a gram of skin, the weight of acetylcholine, 0.078 gamma, would be equal in such a distance to about an inch. This comparison may give us some conception of how small the effective amount of this agent is in a catfish's dark skin. While this determination was being worked out in the Harvard Laboratories another made by the same method was published by Chang, Hsieh, and Lu of the Pekin Union Medical College on the skin of the Chinese snakefish. The determination by these investigators was 0.077 gamma of acetylcholine per gram of skin. The closeness of these two determinations must be regarded as in a measure accidental, for it is unlikely that such uniformity exists. The two numbers, however, show in their approximation the order of magnitude of the amounts of acetylcholine involved and make it fairly certain that these amounts are prodigiously small. Acetylcholine when injected into catfishes with proper precautions will darken them. Hence this substance may well be the agent associated with the dispersing nerve-fibers in their darkening effect on the catfish skin.

If, as is suggested by the preceding consideration, concentrating nerve-fibers act on melanophores through adrenaline, and dispersing fibers through acetylcholine, the melanophores must be subject to much the same type of stimulation by nerve-fibers as by intermedine in that in both instances there is a direct application of a dissolved activator to the outer surface of the color-cell. This tentative view leads to two important conclusions. The first is that the frequently made distinction between stimulation of color-cells by hormones and by nerves is of very little significance, for both methods are in reality the same and depend upon dissolved materials applied to the color-cells. And the second conclusion is that the type of stimulation in the chromatic system falls exactly in line with what is being developed at present for the nervous system in general, namely, that one nervous unit, be it sense cell, nerve cell, or appended cell, is stimulated by another not through purely electric disturbances that pass from one unit to the next, but by substances such as the three herein named. These substances are generated by the discharging unit and activate the receiving one. According to this view such substances are the universal means of passing impulses from one element in the nervous system to the next and are thus of first importance in the physiological integration of nervous activity. They have been variously called chemical activators, neurohormones, transmitters, neurohumors, and the like, but the substances thus designated all act to the same end, the transmission of nerve impulses from one nervous unit to its neighbor. It is gratifying to observe that the study of the color changes of animals supports this general conception of nerve activity, perhaps one of the most important steps in the modern study of the nervous system, that system of organs which has more to do with making us what we really are than any other system in our whole physical organization.

PERENNIAL SNOW AND GLACIERS[1]

By Professor J. E. CHURCH

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Perennial snow differs from seasonal snow chiefly in its survival, and the difference in age between new and old snow may be a matter of days or even hours. Their physical difference, however, may be extreme.

Snow Density

New snow lacks initial coherence though its density may vary from the fluffiest snowflakes to the wettest slush. The lightest density recorded on the ground at the time of fall is 0.4 per cent (0.004) water equivalent in Sodankylä, Finland, during the winter of 1917–18, and a snowfall of 0.5 per cent water equivalent was recorded at Charles City, Iowa, during the winter of 1904–05. However, it is difficult to determine with precision the density of either fluffy snow or feathery rime because of the irregularity of the surface.

Snow density varies primarily with temperature, humidity and wind. The simpler crystals, whether columns or plates, are formed where the air is cold and therefore at high altitudes, whereas the complex star-shaped crystals are formed in relative warmth, and by the interlocking and refreezing of their fern-like points may form combined snowflakes of two to three and probably four inches in diameter.[2]

[1] This is the third in a series of articles by Dr. Church on "The Human Side of Snow." The first appeared in February, 1937, and the second in March, 1942.

[2] "Heavy precipitation (intense rate) favors large flakes, also rather quiet air. The fluffiest snows come in weather too cold for flakes to form except by the enmeshing of the points of complex crystals."—Dr. Charles F. Brooks in Report of Research Committee on the Hydrology of Snow, *Trans. Amer. Geophys. Union*, p. 442, 1942.

Furthermore, because of difference in absolute humidity the columns and plates are sparse and the stars dense. On the other hand, because of simplicity of form the columns and plates will pack together under movement more readily than the stars, thus simulating water-laid sand.

Paradoxically, the cold-born snow, though initially lighter, soon becomes denser than the warm-born snow and quickly approaches maximum density. The transition was noticed during winter observations on the inland ice of Greenland. The measurements were made by Helge Bangsted (unpublished report). In no case did the depth of "new-born" snow exceed 1.4 inches, so small was the quantity. Therefore gravity had little or no part in the increase in density. The temperature ranged from – 17.2° to – 15.0° C. (+ 0.4° to + 5.0° F.). The air was still. The snow density at the two temperature extremes was 3.6 per cent, or about one-third of the formular density of 10 per cent. During the night at a temperature of – 18.1° C. (– 1.0° F.), but during wind the density increased to 11.5 per cent (average of four measurements); where the snow was less exposed to the wind the density increased to only 5.6 per cent.

New snow after apparently only a day or a night of drifting attained an average density of 17.6 per cent. Later in the same period snow only 2.9 inches in average depth attained a density of 24.3 per cent. The density of old snow (depth 5.8 inches) was found to be as high as 28.0 per cent. Drift snow (depth 7.2 inches) after sufficient movement to cover the sled had a density of 35.4 per cent.

Ernie Mack

WINTER SNOW IN ITS EARLY STAGE, SIERRA NEVADA MOUNTAINS

But high-mountaineers are not always fortunate in finding wind-packed snow along their route. Soft snow was found by Whymper at 20,000 feet in the Andes. He wrote, "Louis Carrel could not touch bottom with a twelve-foot pole that he was carrying. It would have continued to descend by its own weight if he had left hold of it . . . as the slope steepened the snow became firmer again."[3] Fitz-Gerald encountered at 18,700 feet on Aconcagua, Chile, in the Andes, "high clouds of driven snow, fine as sand, which nearly suffocated them," and "fell into a huge drift of soft snow."[4] The minimum temperature was $-28°$ C. ($-18.4°$ F.). Of the Himalayas, Odell writes, "Our soft snow on Nanda Devi up to 25,000 feet was in a more or less sheltered reentrant of the mountain, while the exposed summit calotte (25,645 feet) had on the whole a harder compacted surface, although not uniformly so. The more sheltered parts of the flanks of Everest's north face are of soft floury snow, and there is on the whole only restricted windslab on the more salient portions."[5]

However, wind-blown snow quickly acquires a high density which is only slightly increased during the season. The firmness of this snow under foot usually makes mountain ascents easier in winter than in summer.

Capillarity

Snow density is not necessarily synonymous with grain size nor with loss of capillarity known as ripeness.

As snow ages, the more delicate points and angles of the crystals melt or sublimate to rejoin the residual nuclei and increase their size, but at the expenditure of the tiny capillary canals and the larger superficial area of the original grains.

Density expresses water equivalent and crystals of large size and large voids may not possess the capillarity of the smaller crystals unless the voids have become filled by congealing melt water. This lack of capillarity in coarse grains is due to the tendency of melt water to follow the contour of a crystal and form a film about it by surface tension instead of filling the voids. However, if the mass is supersaturated and adhesion is no longer possible, the water flows by voids or conduits, called gravity flow.

New snow exceeds old snow in capillarity but windblown snow because of the smallness of its voids loses little of its early capillarity with age.

On the basis of density, snow may become ripe or unable to sustain its water load at 30 per cent density. The average of many measurements indicates limits of 30.1–36.2 per cent where the crystals are somewhat protected from breakdown by wind action, and 38.2–48.4 per cent where the snow is windblown. After weathering begins, the grain size does not greatly change unless exaggerated by repeated thawing and freezing or by pressure, and the density of the various strata including crusts tends toward uniformity.

Solid ice naturally has no capillarity beyond the surface tension of its exterior and therefore responds immediately to melting.

Insolation

Although warm turbulent atmosphere establishes direct thermal contact with the snow and may produce floods, insolation or exposure to the direct rays of the sun is seasonally more effective because of its longer application. The surface of the snow near midday in sunlight may melt although the air temperature in the shade is $-10°$ C. (18° F. below freezing).

[3] "Travels Amongst the Great Andes of the Equator," by Edward Whymper, pp. 68, 71 (Ascent of Mount Chimborazo, Ecuador).

[4] "The Highest Andes," by E. A. FitzGerald, pp. 89, 92, 114.

[5] Unpublished correspondence, International Commission of Snow, Washington Meeting, 1939.

Ernie Mack

EARLY WINTER SNOW IN THE SIERRA NEVADA

C. H. Diebold, of the U. S. Forest Service, reports that melt rates in the open have been found to be from 1.5 to 2.0 times that in the forest,[6] where shading is relatively complete. Visual evidence of this protection is abundant in the lee of forest screens where the snow line is identical with the line of shade. Likewise in the open, the insolated and shaded sides of snow even of small size melt at unequal rates.

An impressive example to travelers by bus over the Sierra Nevada was the disparity in the melting rate of the opposite snow walls cut by snowplow on the Donner Pass highway in February, 1942. The wall exposed to the sun had reretracted from 6 to 12 inches behind the markers set to indicate the edge of the pavement while the shaded wall was still in its original location or at least was flush with the markers. From bottom to top of the pass the height of the walls varied from approximately 4 to 10 feet but the retraction showed practically no variation with increase in altitude (6,000–7,000 ft.) but rather with the angle of incidence of the sun. During this period at Soda Springs near the summit of the pass the extreme maximum temperature was 46° F. and the minimum −16° F. The mean air temperature above 32° F. (or freezing) was only 2.6° F.

A recent but unusual example of this disparity between sun and air temperature was the formation of snow reliefs in shadows of slender survey-markers set up in the snow. These reliefs, which were plainly visible, had identical orientation, pointing from the sun at the time of its greatest heat efficiency near mid-afternoon.

Dr. Robert E. Horton suggests that, if possible, comparative laboratory or controlled tests be made of melting rates of snow in the same ambient atmosphere with one sample exposed to the sun but the other in the shade. Ideal conditions,

[6] Min. Eastern Snow Conference, Sept. 8, 1941, p. 9 (Mimeo.).

DRIFT SNOW

IN THE LEE OF AN ICE HUMMOCK ON THE GREENLAND INLAND ICE. THE RELATIVE DEPTH OF THE SNOW IS SHOWN BY THE HOLE IN FOREGROUND.

Ernie Mack

EARLY STAGES OF INSOLATION

AND FORMATION OF SUN CUPS NEAR SODA SPRINGS, SIERRA NEVADA, AT AN ELEVATION OF 6,767 FEET.

Ernie Mack

UNEVEN MELTING IN SUNSHINE

CAUSED BY SELF-SHADING. ORIGINALLY THE ROOF WAS EVENLY COVERED WITH SNOW, EXCEPT FOR A SNOW CORNICE ON THE RIGHT. SOON AFTER THE PICTURE WAS TAKEN THE SNOW REMNANT OVERBALANCED AND FELL FROM THE ROOF. APPARENTLY THE INSOLATED FACE OF THE SNOW COVER ON THE LEFT MELTED FOUR TIMES FASTER THAN THE SHADED PART ON THE RIGHT. THE OPAQUE ROOF ACCELERATED MELTING FROM THE SIDES AND BENEATH.

however, would require dazzling, fresh, soft snow, possessing a possible maximum albedo or reflectivity of 87 per cent, in order to exclude the radiation of heat that occurs from opaque objects in the snow. Care must also be taken through air-conditioning to prevent "greenhouse" influence on the insolated sample of snow.

Dr. Brooks suggests "the need for the application of observed insolation to different slopes. The network of U. S. Weather Bureau solar stations in the United States now is almost sufficient for fairly close estimates of the insolation impinging on any slopes. More stations would be desirable."

The depth of penetration of the sun's rays into snow has been found by Kalitin[7] to be 15 centimeters (5.9 inches) for wet snow and 60 centimeters (23.6 inches) for dry. On the Greeland inland ice, 1926–1928, the author found that opaque bodies sank only pencil deep (6–7 inches) into the ice where they re-

[7] N. N. Kalitin, Measurements of the Albedo of a Snow Cover, *Mo. Weath. Rev.*, Feb., 1930.

WIND BLOWN SNOW, CREST OF MT. ROSE, SIERRA NEVADA MOUNTAINS

mained inert. The diameter of the holes was proportional to the area of the opaque material, tiny objects producing a hole the diameter of a lead pencil. Most holes were crescent-shaped and tilted toward the sun as in the case of the pinnacles of the *nieve penitente*. The shallowness of the holes was probably due to the presence of melt water that could not escape.

At 6,000 feet in the vicinity of Soda Springs at the end of March, 1942, suncups in the snow cover had attained a depth of five and one half inches irrespective of the diameter of the opaque material causing them, tiny pipe-stem holes being as deep as the others. Since the water drains off freely, there may be an opportunity here to study the proportional growth of cups of varying areas unaffected by water blanket.

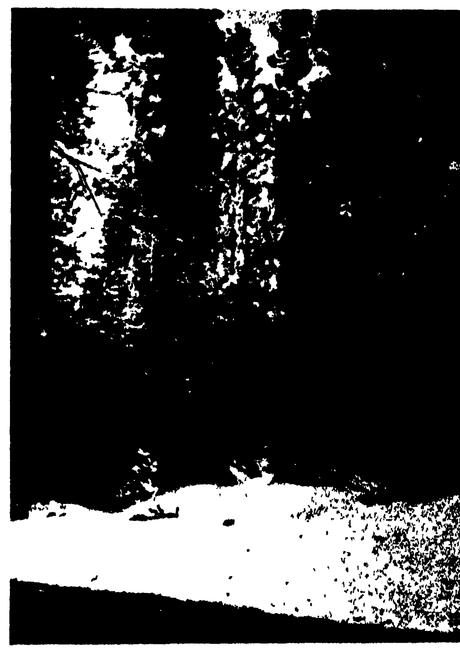
Here within the sweep of the rotary snow plow, ejecta of soil and gravel on the snow surface provided a complete exhibit of radiation effects from the inverted cone containing a single pebble, through the broad cup produced by several separate pebbles acting in unison, to the mound protected from the sun by thick material as completely as the ice beneath the Arctic tundra.

Likewise the pavement after a storm carries the story of radiation in the ice film still clinging to the white concrete and the dry surface of the black asphaltum. Similarly the trees hold their white loads of snow so long as the sun is hidden by clouds but when the sun's rays touch the bark or needles radiation from them disengages the clasp of the snow, which soon slips and falls from its precarious perch.

On the open snow incipient pinnacles, suggesting miniature snow spray, mark the break down of the snow surface. Occasionally an ice window-pane over a depression provides green-house warmth to accelerate melting.

Rates of Melting

The rate of melting depends fundamentally upon the sun's warmth and the length of its application. A daily rate is unsatisfactory, for the length of the melting day varies with altitude and cloudiness. For example, at Soda Springs (6,767 feet elevation) the daily period December–April does not normally exceed 6 hours and the snow surface begins to congeal while the air temperature in the shade above it may still be 35° F. or even higher.



EFFECT OF A TIMBER SCREEN
IN RETARDING THE MELTING OF SNOW IN ITS LEE, NEAR LAKE TAHOE, SIERRA NEVADA MOUNTAINS. THE SNOW AND SHADE LINE ARE IDENTICAL.

During the month of April, the average daily melting per degree F. above freezing for the years 1936–1941 was 0.051 inch of water and the maximum divergence for these years was only 0.015 inch, despite variation in depth and density. The temperature above freezing is plainly the controlling factor.

Flood intensity in snowfields depends upon rate of melting but flood magnitude upon its continuance without interruption. An extremely high natural rate

of melting has been reported by David W. Hullinghorst, U. S. Engineer Office,[8] for the Canacadea Creek Basin, New York, April, 1940, when 1.25 inches of runoff were generated in approximately four hours on the 60-square mile area, or 0.313[9] inches hourly for the period. He suggests that when the snow reaches a critical state, it becomes slush and moves when the crystalline network breaks down. He continues, "The thermal quality appears to be an index of the critical condition but at least one other index, probably density, is required to fully define the critical condition."

[8] Minutes Eastern Snow Conference, Sept. 8, 1941 (Mimeo.).

[9] On the basis of a 6-hour melting day at Soda Springs or .076 in. hourly, the flood melting at Canacadea Creek Basin was four times the long time average at Soda Springs. The temperature is not available.

The estimate by Hullinghorst represents the average melting for an entire basin rather than the maximum rate at any point.

Beneath the snow cover is an individual world inviting the searcher's acquaintance: the formation of crusts and their growth from daily thawing and freezing, the effect of latent heat in accelerating melting and of porosity in hastening freezing, the diurnal freezing and thawing within the snow-cover despite the accepted non-conductivity of snow, the perched strata of rain water imprisoned in the snow isolated from the dry granular snow below and its early release with rising temperature, the crystal change until at last the snow is gone. All these and more are themes in the project of snow studies now organized at Soda Springs by the Nevada Agricul-

Ernie Mack

EFFECT OF OPAQUE MATERIAL IN PITTING THE SNOW
IN THE SOUTH YUBA BASIN OF THE SIERRA NEVADA MOUNTAINS.

tural Experiment Station and the United States Weather Bureau with the informal but sympathetic cooperation of many organizations grown interested in snow through the years.

Glaciers

In its hydrological features the glacier or flowing ice is closely associated with snow, which is its original source. It differs only in possessing the additional factor of perennial existence. Otherwise the cycle of the glacier basin resembles that of the more prevalent snow basin.

The glacier basin is one in which the snow accumulation has exceeded the runoff. This excess in turn is due to temperature, which in its turn may be due to latitude or altitude.

Accumulation

Since the upper reaches of a glacier lie in a zone of prevailing cold, the newly fallen snow and condensation there are less subject to continuous melting though exposed to ceaseless evaporation. If the elevation is excessive, the precipitation will be light. This deficiency, however, is offset by drift snow from outside the glacier area and the self-protective depth of drifts that naturally form on windswept slopes.

The greatest accumulation is necessarily above the point of equilibrium of the glacier and by its head acts as the driving force of the glacier tongue. The accumulation, which in its turn enters the glacier stream, is renewed seasonally or continuously depending on the nature

Ernie Mack

EFFECT OF CONTINUOUS OPAQUE MATERIAL IN PREVENTING MELTING
ALTHOUGH THE SPARSE MATERIAL ACCELERATES IT. NOTE THE RESULTING WAVELIKE EFFECT.

of the precipitation cycle, but its amount is variable.

Formation of Firn or Névé and Glacier Ice

The snow in glacier basins is both seasonal and perennial, the relative amount of each depending upon the conserving power of the slopes. This is indicated roughly by the relative area of the glacier surface. Yet not all snow that falls on the glacier surface can be considered perennial, for it may melt and run off with other seasonal snow particularly on the lower reaches or fringes of the ice and come out in the glacier stream below.

The distinction between seasonal and perennial snow or firn is as already suggested one of survival, which may carry with it a greater maximum density due to concentration of melt water from persistent freezing. The maximum density of seasonal snow appears to range from 35 to 58 per cent. The density of firn may range from even less to that of glacier ice, 86 to 91 per cent. The initial density, however, is usually nearer 45 per cent.

The physical change of snow to firn is one of crystal growth caused by evaporation and pressure but accelerated by melting. As expressed by Seligman,[10] the delicate plumes of newly fallen snow gradually evaporate and the water vapor condenses upon the residual snow crystals and thus enlarges them. The physical properties of the snow and firn at successive stages have been set forth by him in the following table:

Kind of snow	Specific gravity or density	Grain size (millimeters)	Depth (meters)
Settled snow	0.291	0.1–0.2	0.16
Early firn	0.437	0.3–0.5	1.10
Denser firn	0.463	0.6–1.3	2.70
Old firn (3 yr.)	0.72		14
New ice (6 yr.)	0.80		23
Pinnacle ice	0.92		

The air spaces between the individual flakes of new snow continue as a ramifying network of air channels throughout the firn mass. The extent of the air channels diminishes as the density further increases and the channels become interrupted and sealed into noncommunicating chambers. This stage is snow- or glacier-ice, and is distinguished from water-ice by its larger content of imprisoned air, which imparts a grayness to its appearance. This was very obvious on the inland ice of Greenland where vertical fissures had filled with water and frozen into clear blue ice. These appeared to be the source of the blue bands in the icebergs.

Since the air channels in the ice are no longer continuous, ice is not permeable to water except where fissured or traversed by *mühlen* down which surface waters spiral into the depths.

Glacier fields have been classified into alpine, sub-polar, and polar on the basis of temperature, but unfortunately precipitation and altitude modify the simple relationship of latitude, so that heavy melting occurs even at high latitudes where the elevation is low. Only above 2,500 meters in Greenland at latitude 70° N. was melting entirely absent, and slight melting in Antarctica occurs near sea level even above latitude 80° S.

The fundamental factor of pressure separate almost wholly from melting has been observed by Ernst Sorge,[11] at Eismitte, at an altitude of 3,000 meters (9,842 feet), Wegener's central station

[10] Gerald Seligman, The Structure of a Temperate Glacier, *Geog. Jour.*, 97: 295–317, 1941.

[11] Ernst Sorge, The Scientific Results of the Wegener Expedition to Greenland, *Geog. Jour.*, 81: 333–344, 1933; Glaciologische Untersuchungen in Eismitte: Wissenschaftliche Ergebnisse der Deutschen Grönland-Expedition, Alfred Wegener, 1929 and 1930–31, vol. 3.

in Greenland. In 21 annual layers, only at one single spot was an ice crust found, and this was no larger than a hand.

Here the mean annual increase in the inland ice was found to be 31.4 centimeters (12.4 inches) water. The snow cover was penetrated to a vertical depth of 15 meters (49 feet), or through 21 years of snow accumulation. An increase in density was measured from 34 per cent at the surface to 54 per cent at 15 meters or 46.7 per cent average density for practically the entire depth.

Because of lack of cohesion the weight of the snow was unusually effective in increasing its density by expulsion of air, the sound of which appeared to be distinctly audible. At 475–785 centimeters the daily settling averaged 2.7 millimeters; at 695–1005 centimeters, 1.9 millimeters. At 15 meters the rate of increase in density was approaching the vertical. The temperature at 16.6 meters was −28.65° C. (−19.6° F.) and below the influence of seasonal changes. Sorge estimates that a depth of 200 meters will be necessary to compress the snow to 84 per cent, and 1,000 meters to 90 per cent.

The "ice cap" in Central Greenland was measured seismographically by Wegener as 2,500–2,700 meters. At 120 kilometers from the western rim of the inland ice, where the glacier ice is exposed, the ice was approximately 1,700 meters thick. Since the elevation above

Ernie Mack

BARRIERS TO INSOLATION

THIS PICTURE SHOWS THE RELATIVE EFFECTS OF TOWEL, BRANCH AND HEAVY GRAVEL IN PROTECTING SNOW COVER FROM INSOLATION. THE TOWEL IS HUNG UP ON THE SNOW CONE PRODUCED BY ITS SHELTER. THE CONE BEHIND THE FALLEN BRANCH IS SLIGHTLY EXPOSED TO INSOLATION AS COMPARED WITH THE FORMER AND CONSEQUENTLY IS SMALLER. BOTH HAVE BEEN BOMBARDED WITH GRAVEL SINCE THEIR INCEPTION.

sea level at 120 kilometers is approximately 700 meters lower than at Eismitte (400 kilometers), it can be fairly assumed that the glacier ice found at the former point would appear at within 700 meters beneath the surface of the snow at Eismitte, where accumulation is at its full activity.

At Jungfraujoch in the Alps in a shaft at 3,640 meters altitude, the firn was found by Seligman to attain a density of 69 per cent at the depth of 20 meters (66 feet) though without further increase in density to 28 meters (92 feet), but in crevasses at 3,330, 3,200, 3,140 meters altitude densities of approximately 86, 84, and 85 per cent were found at depths of 23, 17, and 13 meters respectively. The transitional zone from firn to ice was found at 19, 16, and 11 meters in each, but some of the original firn from which the glacier ice had been formed had disappeared probably by melting, for the firn line occurred at 3,020 meters, immediately below, or at 620 meters lower elevation than the initial shaft.

Seligman remarks that the change from permeable firn to impermeable firn or ice is not accompanied by a marked rise in either the density or the grain size. Furthermore, that at the latitude and altitude of Jungfraujoch zero temperature, Centigrade, ruled below the depth of 15 meters throughout the year. In the case of the open crevasses, situated 300 to 500 meters lower, air temperature has evidently had access to the surface and the depth to the transitional zone of firn to ice has been reduced by melting of the more recent seasonal layers.

Is there a pressure melting point at which the continuous air channels in the

Ernie Mack

BREAKDOWN OF SNOW-CRYSTALS ON SURFACE OF SNOW


Ernie Mack

SNOW AND ICE "LACE" FROM THE SPRAY OF A MOUNTAIN STREAM
SHOWING THE STRATA OF ACCUMULATION AND THEIR WEATHERING.

firn are squeezed out or diked into pockets? This may be indicated by the finding by Oxford University's Arctic expedition under A. R. Glen to North East Land in 1935–36 that "at the depth of 70 feet in the ice cap the temperature was fairly constant at 0.0° C. but at a somewhat greater depth an unfrozen lake was found."[12] Possibly confirming this was the presence of "weeping" at the face of the Greenland inland ice noticed by the author in midwinter of 1927–1928.

Spitzbergen and Iceland, classified by Ahlmann as subpolar, afford ideal fields of glacier study because of low elevation, heavy precipitation, and seasonal temperature influence.

[12] The Glaciology of North East Land, *Geografiska Annaler*, vol. 21; The Oxford University Arctic Expedition, North East Land, 1935–36, *Geog. Jour.*, 90: 289–314, 1937.

The high initial density of the snow at the former, at altitudes of 845–850 meters, as compared with central Greenland, at an altitude of 3,000 meters, is shown in the following table:[13]

	Depth of meas. (centimeters)	Percentage density	Observer
Central Greenland	0 to 238	36.6	Sorge
	0 to 497	39.8	"
	0 to 1,345	46.7	"
Spitzbergen	22 to 235	54.2	"
	0 to 400	57.0	Ahlmann

Sverdrup's investigation showed that

[13] Ernst Sorge, Glaziologische Untersuchungen der Deutschen Spitzbergenexpedition, 1935, *Trans. Internat. Commissions of Snow and of Glaciers*, Edinburgh, 1936, *Bull.* 23, *Internat. Assoc. of Scientific Hydrology*, pp. 733–43.

"the negative winter temperature had disappeared by the beginning of August and that the temperature of the firn was then at melting point throughout. The most important factor in bringing this about was apparently the percolating thaw water. Thaw water, regelating on the firn grains, is, in Ahlmann's opinion, also of decisive importance to the slow growth with depth of the individual firn grains and their grapelike agglomerations.

A striking example of transition from firn to glacier ice was found by Ahlmann in Iceland in 1936, where accumulation and ablation are "inconceivably" large. To quote from his report,[14] "At the end of the accumulation period proper, in the middle of May, the 1935-36 annual layer in the eastern part of Vatnajökull amounted to 700 centimeters of snow, corresponding to about 3,700 millimeters (145.6 inches) of water. . . . In the higher parts of the accumulation area 300–400 centimeters of snow remained of the layer deposited from March, 1934 to the autumn of 1935.

"The 1935–36 annual layer was well stratified by a great many ice crusts and layers of water-logged snow. At a certain depth in the pits, varying with the altitude above sea level, the snow began to assume negative temperature, which fell to $-3°$ C. or $-4°$ C. deeper down. The water-logged snow remained at freezing point throughout the sections, and so did some of the ice crusts.

"At the boundary surface formed in the autumn of 1935 the structure of the material suddenly changed from snow to coarse-grained, porous firn. The recrys-

[14] Hans W: son Ahlmann and Sigurdur Thorarinsson, Vatnajökull, Scientific Results of the Swedish-Icelandic Investigations, 1936–37, *Geografiska Annaler*, 19: 146–229, 1937.

RIPPLE MARKS IN BOTH SNOW AND ICE

CAUSED BY EVAPORATION ACCELERATED BY WARM DOWNSLOPE WINDS ON THE INLAND ICE OF GREENLAND. THE WARMTH CREATES MOISTURE WHICH IS MORE SUSCEPTIBLE TO EVAPORATION THAN FROZEN SNOW OR ICE. THE DEPTH OF THE SNOW IS SHOWN BY THE PIT IN THE LEFT FOREGROUND. SEALED ICE CRACKS, SUCH AS THAT ON THE RIGHT, APPEAR AS BLUE BANDS IN ICEBERGS.

Harold Orne

FROSTED BELL, SUMMIT HOUSE, MT. WASHINGTON, N. H., AT 6,293 FEET

tallization of this firn to glacier ice could also be followed and studied."

Such coarse-grained, porous firn, suggesting hailstones saturated with water, so unconsolidated that the author sank ankle-deep in it, was observed in August, 1928, at 4,500 feet elevation at the edge of Nugssuak "ice cap," Umanak Fjord, Greenland. The impending winter would quickly change the mass to ice aggregate. Seligman proposes the growth of crystal grains in glacier tongues as the subject of his next research and Sorge would obtain firn cores at greater depths in the back of the Greenland ice. Can a snow sampler of thirty times the present length be developed to accomplish this?

The persistence of grain characteristics where not too greatly affected by melt water has been noted by Sorge in Greenland and Spitzbergen and has made possible the identification of seasonal strata by their density and the summer and winter accretions in them. Each region shows its climatic characteristics.

For example, in Greenland the winter snow is denser than the summer snow. For the summer snow is coarse grained and loose and in the higher places of the inland ice is crusted little or not at all. The winter snow, on the other hand, is fine grained and becomes very solidly packed, often through the storms of the winter. This slight excess of density is preserved at least to the depth of 15 meters. In Spitzbergen the summer deposits melt and freeze and are denser than those in winter, when the snow falls

as powder snow of much lighter density. In Iceland rain and snow fall in both summer and winter indiscriminately and make identification difficult.

CONDENSATION VS. EVAPORATION

In zones where the humidity is high, condensation may exceed evaporation, but in the Arctic, as represented by the Greenland ice, measurements during 1928 and 1929 indicate an evaporation five times as great as condensation for both snow and ice and ten times as great in the case of water.[15]

Rime formation reaches its largest proportions on mountain tops but is restricted in area and because of its porous character is subject to rapid dispersion by evaporation.

Indeed, at high altitudes where cold and aridity prevail, evaporation exceeds melting and results in the spectacular sun pits or *nieve penitente*, perhaps better termed "sun spikes or blades." These have been discussed particularly by François E. Matthes and Humberto Barrera.[16] Sun pits and spikes four feet vertical have been seen on Mauna Kea, Hawaii, on the Tropic of Cancer (23° 27′ N.) at 13,250 feet by Chester K. Wentworth[17] and parallel cases by N. E. Odell at 18,500 feet on Mount Everest[18] at 28° 30′ N. Odell reports that "no melt-water at all was seen either in the cups and pits nor yet trickling away from the snow surfaces. The prevailing diurnal air-temperatures here are well below the freezing point, especially at this time of the year (April)".

ABLATION

The active melting of glaciers is controlled largely by altitude and insolation. At high altitudes the ablation takes the form of accelerated evaporation. On the North gap of Mount Everest at 23,000 feet Odell found the midday shade temperature only 29° F. while the sun temperature was 105° F. The visible melting, however, was surprisingly little. "High up on the face of Mount Everest a considerable snowfall will in spring and summer have evaporated into thin air in a few hours without any visible melting."

The seasonal snow cover on the glacier, on the other hand, can delay melting since "much more heat radiation is absorbed by snow-bare ice than by snow. The albedo of wet snow is 64–70 per cent, of ice only 50 per cent." Ahlmann found the greater reflection by the snow "clearly indicated by the ablation curves of the Fourteenth-of-July Glacier, Spitzbergen, for different times of the summer: they bend abruptly at the temporary snow limit."[19]

Therefore, if the snow cover is thick and low, the glacier will be protected, but the retreating seasonal snow or firn line will leave the ice foot exposed to accelerated and uncontrolled melting.

Fortunately, however, when the sky is clear, especially at high altitudes, the surface temperature not exposed to direct sunlight is, on account of radiation, always below that of the neighboring air. The difference is almost as great as

15 J. E. Church, Meteorological Studies: A. Climate and Evaporation in Alpine and Arctic Zones, Report of the Greenland Expeditions of the University of Michigan, Part II, pp. 7–59.

16 (a) François E. Matthes, Ablation of Snow Fields at High Altitudes by Radiant Solar Heat, *Am. Geophys. Union Trans.*: 380–85, 1934; (b) Humberto Barrera, A Study of the "*nieve penitente*" of the Chilean Andes, Trans. Internat. Commissions of Snow and Glaciers, Edinburgh, 1936, Bull. 23, Internat. Assoc. of Scientific Hydrology, pp. 587–622.

17 C. A. Wentworth, Ablation of Snow under the Vertical Sun in Hawaii, *Am. Jour. of Science*, 238: 112–16, 1940.

18 N. E. Odell, Ablation at High Altitudes and under High Solar Incidence, *Am. Jour. of Science*, 239: 379–82, 1941.

19 Hans W:son Ahlmann and Sigurdur Thorarinsson, The Vatnajökull Glacier, Preliminary Report of the Work of the Swedish-Icelandic Investigations 1936–1937, *Geog. Rev.*, 28: 417, 1938.

U. S. Antarctic Service

THE ANTARCTIC SNOW—PRESENT LURE OF THE SNOW SCIENTIST

A SNOW CRUISER WHICH IS BERTHED AT WEST BASE, ANTARCTICA, VIEWED FROM AN AIRPLANE AT AN ALTITUDE OF ONE HUNDRED FEET.

at night, when the surface temperature may be five, ten, or even fifteen degrees C. below the temperature of the air (Dorsey).[20] Consequently the crispness that instantly occurs on the snow fields at sunset and the cessation of melting in the Arctic as the sun slightly declines.

THE REGIME OF GLACIER STREAMS

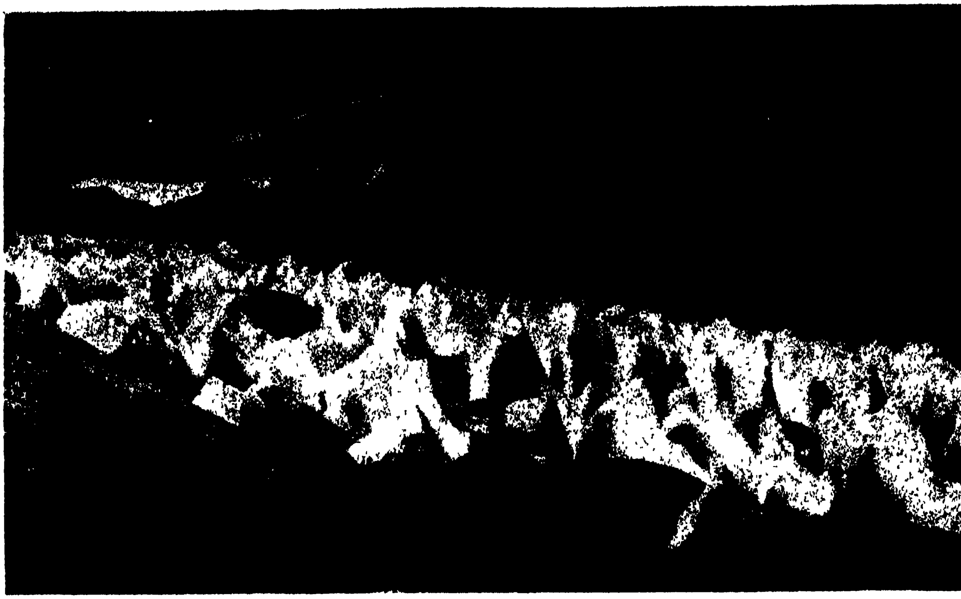
The regime of glacier streams can be best presented and understood against the background of rain- and snow-fed streams. Secondo Alfieri has done pioneer work in this field.[21]

In the Italian Alps and Appenines he has selected five basins, three of which are snow and glacier, one snow, and one mostly rain. The comparison covers seven years, 1931–1937. These glacier basins are somewhat higher than those of the Central Sierra Nevada, and are slightly farther north. Their peak flow should therefore be later.

The essential characteristics of these

20 N. Ernest Dorsey, Properties of Ordinary Water-substance in All its Phases: Water-vapor, Water, and all the Ices, p. 492.

21 Secondo Alfieri, Influenza della Neve e del Ghiaccio sulla Portata dei Corsi d' Aqua: Internat. Com. of Snow and Glaciers, Washington, 1939 (awaiting publication).



Virgil D. Sisson, Kindness of Chester Versteeg

DESICCATED SNOWFIELD

WITH SUN PITS ALMOST ENTIRELY VANISHED, LEAVING THE SUN BLADES STANDING ALONE. THE LOCATION OF THIS SCENE IS IN THE CENTRAL HIGH SIERRA AT 13,000 FEET ON THE NORTHERN APPROACH TO "THE SPECTATOR," ON THE SIERRA CREST AT THE HEAD OF LAMARCK CREEK NEAR PIUTE PASS WEST OF BISHOP, CALIFORNIA. PHOTOGRAPHED AUGUST 3.

C. A. John Hendry

UNCONSOLIDATED FIRN AT EDGE OF NUGSSUAK "ICE-CAP"

IN ARCTIC MID-SUMMER (AUGUST) AT 4,500 FEET, UMANAK FJORD, GREENLAND. A CHARACTERISTIC OF NATURE'S PERSISTENT ADJUSTMENT WAS A CLUMP OF ICELAND POPPIES MORE DELICATE IN STEM AND COLOR THAN THEIR CALIFORNIA COUNTERPART, BLOOMING AT THE EDGE OF THIS PERENNIAL SNOW IN GRAVEL SATURATED WITH ICE WATER. HERE WAS NATURE EMERGING FROM ITS ICE AGE.

TABLE I

HYDROLOGIC CHARACTERISTICS OF ALPINE BASINS

Stream and gaging station	Location	Area of basin (Square kilometers)	Mean altitude of basin (meters)	Glacier surface (Square kilometers)	Mean altitude of glacier (meters)	Proportion of glacier to basin (per cent)	Coefficient of annual runoff to precipitation (Average, 1931–1937)
—Glacier—							
Lys a D'Ejola	Alps Dora Baltea (Monte Rosa)	30.4	3,112	14.4	3,580	47	1.39X
Frodolfo ai Forni	Adda Superiore	48.5	2,800	22.8	3,200	47	2.04X
Rutor a Promise	Dora Baltea	49.8	2,616	13.8	2,900	28	1.31X
—Snow—							
Corsaglia alla Presa Centrale Molline	Maritime Alps	88.5	1,530	Generally snow at higher altitudes remains on ground for several months.			0.82X
—Rain—							
Reno a Pracchia	Northern Appenines	40.9	890	Limited amount of winter snow but melts quickly.			

five basins are shown in the accompanying table.

The heavy melting of the glaciers that has been in regression for several years naturally increases the coefficient of runoff with reference to annual precipitation. But Alfieri's reference to nonglacier basins in which on certain years the runoff equalled or exceeded the precipitation indicates lack of sufficient precipitation data, probably at higher altitudes.[22]

However, even if the coefficient of runoff is overlarge, it still represents the relative effect of ice, snow, and rain on runoff.

Of the glacier basins, the Frodolfo seems to have the most favorable altitude for melting of its ice reserve. The Lys is too high and the Rutor has too small a glacier for its area. The Corsaglia, though having no ice reserve, maintains an extremely high coefficient for snow. The Reno, owing to losses of precipitation in the frequent repriming of its soil, has the lowest coefficient of all.

The monthly and seasonal phases of precipitation and runoff can most clearly be shown in percentages of the annual (Table II).

The precipitation is quite evenly distributed throughout the year with slight excess in the summer months. This, however, has little effect on the regimen of the ice- and snow-fed streams, for their phases are chiefly due to temperature acting upon accumulation.

The glacier streams because of the low temperature at their high altitude and reserves of ice have their major runoff during June–September. The lower snow-fed basin, Corsaglia, has its major runoff in March–June, which ends in the exhaustion of the seasonal storage of

[22] The Rhone Glacier Basin (24.19 sq. km.) has 10 precipitation stations; the Montreux Basin (13 sq. km.), 50 during 1931–1938; Lake Davos Basin (9.47 sq. km.), 16. All should thus be ideal for snow and runoff studies.

TABLE II

MEAN PRECIPITATION AND RUNOFF, MONTHLY PERCENTAGE OF ANNUAL

	Annual	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
	Glacier—Lys a D'Ejola (Sq. km 30.4; ice 47%; mean altitude 3,112 meters)													
Precipitation	1,260 mm	4.3	5.5	8.5	8.5	12.5	8.8	6.7	7.6	10.6	8.2	10.6	8.3	
Runoff	55.5*	0.6	0.5	0.5	1.9	9.0	*19.0*	*23.5*	*23.3*	*13.7*	5.6	1.6	0.8	Major runoff 79.5%
	Frodolfo ai Forni (Sq. km 48.5; ice 47%; mean altitude 2,800 meters)													
Precipitation	894 mm	5.1	4.7	6.3	6.9	1.0	10.6	12.5	11.7	10.6	10.3	6.5	4.7	
Runoff	57.9*	0.8	0.6	0.5	0.7	4.0	*18.2*	*28.4*	*23.4*	*15.0*	5.6	1.7	1.0	Major runoff 85.0%
	Rutor a Promise (Sq. km 49.8; ice 28%; mean altitude 2,616 meters)													
Precipitation	1,484 mm	7.6	6.0	10.2	7.5	8.0	7.7	8.2	9.9	11.5	6.9	7.5	9.0	
Runoff	61.8*	1.0	0.8	0.8	1.9	9.7	*21.8*	*25.2*	*19.4*	*11.8*	4.4	1.9	1.3	Major runoff 78.2% (5 mos. 87.9%)
	Snow—Corsaglia alla Presa della Centrale Molline (Sq. km 88.5; mean altitude 1,530 meters)													
Precipitation	1,536 mm	6.0	4.3	12.2	8.3	11.8	6.8	5.5	6.4	7.4	8.9	14.6	7.8	
Runoff	40.1*	3.3	3.6	*7.3*	*15.2*	*25.4*	*13.1*	6.4	3.1	3.8	6.7	7.1	4.8	Major runoff 61.0%
	Rain mostly—Reno a Pracchia (Sq. km 40.9; mean altitude 890 meters)													
Precipitation	2,189 mm	7.9	7.9	11.9	8.2	8.5	8.5	2.4	3.2	4.9	15.0	13.7	10.0	
Runoff	51.9*	*9.9*	*9.7*	*17.6*	*8.6*	*7.9*	*5.6*	1.7	0.8	1.0	*9.8*	*15.5*	*12.1*	Min. runoff 3 mos. 3.5%

* Liters per second per square kilometer.

snow. The excess of 20 per cent in the major runoff of the former three (80.9 per cent) over the latter (61.0 per cent) indicates the present wastage of ice reserves. If annual replacement were equal to ablation, the major runoff should be more comparable with that of the snow, except that the runoff will last longer.[23]

The rain basin, Reno, has a continuous runoff, lagging apparently behind the rainfall except that its dry season in July–September synchronizes with the three months of minimum precipitation.

The forecasting of the runoff of snow and glacier streams requires merely a normal or standard of comparison of the annual snow cover and the ablation of the ice. As early as 1914 Dr. Alfred de Quervain and Dr. R. Billwiller began sampling the annual reserve of snow in the *névé* of glaciers.[24]. This system should be extended to the entire water-

[23] The amount and duration of melting is proportional to altitude. For example, during 1930–1937 the average amount and period of melting of the glacier of Bors (3,050 m.) were 189 cm. (6.2 ft.) and 2 mos.; of the Lys at Salzen (2,350 m.), 790 cm. (25.9 ft.) and 5 mos.

[24] J. E. Church, Present Methods of Glacier Study in the Swiss Alps, *Mo. Weather Rev.*, 52: 264–66, 1924.

shed both non-glacier and glacier in the same manner as applied to snow basins. Because of the ruggedness of the terrain the percentage method should preferably be used. Where possible, stream-gaging stations should be established particularly in the non-glacier areas as a check on the accuracy of the snow-surveys. Precipitation stations would be a valuable supplement.

Since fluctuations in temperature can not be forecast, estimates should be confined to the total major runoff rather than to peak flows.

Through the pioneer efforts of Dr. Otto Lütschg-Lötscher[25] photogrammetric surveys of the fluctuation of glaciers in volume now provide an accurate method of determining the seasonal water content of the ice as of a reservoir. The net relationship between annual accumulation and dissipation can thus readily be determined. Charts of the Upper Saas Valley, Monte Rosa Massif, and Upper Grindelwald Glacier in the Jungfrau Group make these areas highly desirable initial points in the development of snow-surveying in the Alps.

Glacier Flow and Icebergs

The alluring field of glacier flow and iceberg migration has been opened wide by Gerald Seligman, Dr. Max Demorest, and Commander Edward H. Smith of the Ice Patrol and provides a further chapter on the romance of snow and ice.

Max and Becky Demorest have studied ice flow in its mountain bed and placed glacier ice under laboratory compression. Commander Smith has brought ice from the Greenland sea for them to study, and has begun a census of icebergs enroute from their parent glaciers to their melting point in the Atlantic sea-lanes the better to forecast their frequency.

Now Max lies dead in the distant North in service of his science and his country. His memorial is the hearty acceptance of his discoveries by François E. Matthes,[26] interpreter of glaciology, and the bestowal of a Guggenheim and other fellowships to finance his plans still scarcely within the threshold of achievement.

But he has the frozen glaciers to share his quiet. No better spot for his eager spirit.

On the Back of the Great Ice[27]

"And Abraham sat in the door of his tent and gazed down upon the plains of Jordan." Thus we sit tonight on the great ice 1,500 feet in air and gaze down upon the panorama of Inner Greenland stretching in haze and luminous sunset color toward the distant sea. It might well be out West on the rim of Death Valley, save that here we look down a broad canyon with a spreading, winding river dazzling in the sun like silver, and in a parallel valley upon a large lake rivaling Taserssuak in size. Beyond multitudinous hills rises the slope of Pingo looking like some Northern Ararat. Beyond the purple haze rides a long thin band of clouds. The rolling sea of ice is in front.

[25] Dr. h.c. Otto Lütschg, Zum Wasserhaushalt des Schweizer Hochgebirges: Presidential Address Internat. Assoc. Sci. Hydrology, Washington, 1939 (awaiting publication). Pre-publication copies available.

[26] François E. Matthes, Glaciers, Physics of the Earth—IX, Hydrology, pp. 149–219, National Research Council.

[27] From the author's diary.

PHARMACOLOGY OF THE SULFONAMIDE DRUGS

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THERE are few drugs with systemic effects that are being so widely used and in such large doses as the sulfonamides. A proper understanding of their behavior in the body is especially necessary for their safe and successful use. Laboratory experience has emphasized the wide variations met when going from one species of animal or bacterium to another; and what is equally important, the considerable differences in the toxic or therapeutic response met when studying large groups of individuals or several strains of the same organism.

Excellent reviews of this subject have recently been made by Marshall[1] and by Goodman and Gilman[2] and no complete survey will be attempted in this paper.

ABSORPTION AND EXCRETION

Absorption from the stomach is negligible for all drugs of this group. Sulfanilamide is readily absorbed throughout the remainder of the alimentary canal, as well as from the serous cavities and from open wounds. When given by mouth, water accelerates absorption, presumably by hastening the passage from the stomach to the intestines. Absorption of sulfanilamide is greatest in the first four to six hours and is practically complete in twenty-four hours. As proof of this only traces appear in the stools and 70 to 95 per cent. is recovered in the urine, mostly within twelve hours. With normal kidney function, excretion is complete in two to three days.

The sulfanilamide derivatives in current use are absorbed more slowly and with less regularity. This is due in part to their poor solubility. Sulfapyridine in particular is slowly, irregularly and poorly absorbed. As much as 20 per cent. may escape absorption and appear in the stools. Absorption from the colon and rectum is slight.

Sulfathiazol is better absorbed and a smaller percentage (0 to 10 per cent.) appears in the stools. Published reports by Feinstone and others on sulfadiazine indicate a higher and more sustained blood level, with slower excretion. In man approximately two thirds can be recovered in the urine in forty-eight hours. Studies of fecal excretion are lacking.

Sulfaguanidine was found by Marshall to be absorbed only from the small intestine. Excretion in the urine varies from 5 to 70 per cent. Only a limited capacity for absorption exists; hence, with increasing doses absorption does not increase proportionally. By giving large doses it is thus possible to get high concentrations throughout the alimentary tract, and correspondingly low concentrations in the blood.

The most recent addition to the series of sulfonamides designed for intestinal disinfection is succinyl sulfathiazol. Experimental evidence indicates that less than 5 per cent. of this drug is absorbed, and it has not been possible to produce pathological changes in rats or monkeys from large doses given orally for one month.

These poorly absorbed sulfonamides can suppress the normal coliform bacterial flora of the intestines to an extent that could not be previously accomplished. Elvehjem and co-workers demonstrated an interference with the

[1] E. K. Marshall, Jr., *Annual Rev. Physiol.*, 3: 643, 1941.

[2] L. Goodman and A. Gilman, "The Pharmacological Basis of Therapeutics." New York: The Macmillan Company.

growth of rats which they interpreted as a deficiency state due to suppression of a growth factor normally synthesized by these intestinal bacteria. Daft, Sebrell and co-workers have produced some characteristic pathological changes when sulfaguanidine was administered to animals upon a diet deficient in vitamin B complex. The importance to the clinic of these significant experiments remains to be established.

Distribution

Sulfanilamide is notable for its distribution throughout all the tissues and body fluids in concentrations closely approaching that in the blood. Until recently it was believed that the sulfonamides existed in the body in a free, diffusible state. However, Bernard Davis has shown that they attach themselves to the plasma (and presumably tissue) proteins; the extent of binding varies from 5 per cent. with sulfanilamide to 70 per cent., with sulfathiazol. Intimately related to this phenomenon is the problem of ionization of the sulfonamides. It has recently been shown by C. L. Fox, F. Schmelkes and others that sulfanilamide at the pH of the body ionizes very little, while some of the more active sulfonamides dissociate to a high degree. Both binding and ionization are important influences upon the behavior of drugs in the body, and these effects throw light upon certain variations in the distribution of sulfonamide compounds, such as the lower concentrations of sulfathiazol attained in the spinal fluid.

Further remarkable characteristics of the sulfonamides are their relative lack of irritating effects when applied locally, and the high tolerance of the tissues to them without apparent harm to the defense mechanisms of the body.

Fate in the Body

Surprisingly few of the organic chemicals which are absorbed escape some change during their sojourn in the body. With the sulfonamides this consists chiefly of the introduction of an acetic group in the free amino radical. It is not determined whether this change is an attempt on the part of the body to render the compound less toxic or whether it is simply following a process which is physiological for certain metabolites and into which pattern certain foreign substances such as the sulfonamides seem to fit. Actually the acetylated sulfonamides are more toxic to the host, and furthermore they are practically devoid of therapeutic activity, so that this change is quite undesirable from the standpoint of drug therapy.

The extent of acetylation varies widely with the compound, with the species and to a lesser extent with the individual. With sulfanilamide there is little or no acetylation in the dog and frog, while it occurs to 50 per cent. or more in the rabbit and man. From 25 to 75 per cent. of the sulfanilamide administered to man is acetylated.

Sulfapyridine shares this objection to as great or to a greater degree. In man from 15 to 75 per cent. may be acetylated. Sulfathiazol is conjugated to a less extent and in man reported values are up to 30 per cent. Sulfadiazine shows very little conjugation in the blood, but 10 to 60 per cent. of the drug in the urine is acetylated. The excretion by the kidney of the N-4-acetyl derivatives is more rapid than that of the free compounds. Acetyl sulfonamides, therefore, leave the blood faster and the amount of acetylation in the blood may not be a true index of the total acetylation which will be found in the urinary output.

Acetylation of the amino group is a disadvantage for several reasons. Such acetyl derivatives are inactive therapeutically; they are of increased toxicity; the process of acetylation imposes a physiologic burden on the body; and finally the acetyl derivatives of many compounds are sufficiently insoluble to

be precipitated in crystalline form in the urinary tract to the extent that kidney damages and stone formation may result.

Because of technical difficulties, knowledge of the fate of these compounds has been limited largely to the free amino group. Oxidation products of this group are known to be of greatly increased toxicity and of possible interest in mechanism of action. In the test-tube sulfanilamide can be broken down by chemical means and by ultra-violet light (Fox, Shaffer, Rosenthal), extensive change occurring at both ends of the molecule. Our information will be incomplete until it is determined to what extent such changes occur in the body. Scudi has shown that sulfapyridine is excreted in part as a hydroxy derivative.

Mechanism of Action

It is generally agreed that the action of the sulfonamides is primarily upon the organisms causing disease. In the test-tube, under conditions favorable for cultivation, this action is not impressive, and is chiefly an inhibition of growth. While there is a general correlation between effect in the test-tube and in the body, many exceptions are encountered when studying different compounds and different organisms. As an example may be cited the susceptibility of the alpha streptococci (viridans) in the test-tube and their resistance to chemotherapy in the body.

Such variations may be made clear with increasing knowledge. It may be reasonably assumed from present evidence that the sulfonamides act by inhibiting the growth of bacteria in the body so that the natural defense mechanisms may successfully cope with the infection. The importance of the natural defenses in the success of chemotherapy is thus sharply emphasized.

The first attempt to explain bacterial inhibition was made by Mayer on a basis of oxidation of the amino group to a hydroxylamine. This product is much more active in the test-tube, but highly unstable. Mellon and coworkers advanced this theory by virtue of the inhibiting effects of these oxidation products on catalase and perhaps other enzymes which would lead to the accumulation of toxic metabolites, specifically hydrogen peroxide in the bacterial cell.

The inhibition of bacterial growth on a basis of interference with the metabolic requirements was proposed by Lockwood, who demonstrated that peptones could antagonize the bacteriostasis of sulfanilamide. English workers established the occurrence of antisulfanilamide factors in many cell extracts, cumulating in the demonstration by Woods[3] that p-aminobenzoic acid or a closely related compound was present in such extracts and that traces of it could neutralize sulfonamide bacteriostasis. This antagonism is specific, and we have found no effect of p-aminobenzoic acid on the various antiseptics, such as formalin, peroxides, mercury compounds or upon the action of antiserum.

Woods has postulated the role of p-aminobenzoic acid or a derivative as that of an essential metabolite for plant and perhaps animal organisms, a vitamin for bacteria, which sulfanilamide by virtue of its similar chemical structure can replace in the enzyme system and thereby interfere with its utilization.

This postulate satisfied many of the puzzling features of the problem, such as the inactivity of the isomers of sulfanilamide, the lag observed in the bacteriostatic action, the inhibition of growth rather than the killing effect of the drug on bacteria.

More information is needed regarding the presence and function of p-aminobenzoic acid both in the bacterial cell and in the animal organisms, and the reasons for the high tolerance of animal

[3] D. D. Woods, *Brit. Jour. Exptl. Path.*, 21: 74, 1940.

tissue to the sulfonamide drugs. It remains to be seen whether the immunity of certain bacteria to sulfonamides is related to their aminobenzoic acid metabolism. The postulate is of immense practical value as a working hypothesis for the development of new compounds, as well as for opening new fields of investigation.

Recent work has brought out that the degree of activity of a sulfonamide compound may be fundamentally related to its physical characteristics. Mention has been made that the sulfonamides vary in the extent to which they are bound to body proteins and the extent to which they are ionized in the body fluids. The several investigators responsible for these observations have related them to antibacterial action. The *degree* of therapeutic action has been shown to be a function of that portion of the drug bound to the proteins, and likewise to that portion of the drug which is ionized. A correlation has been established between acidic dissociation constants and antibacterial action that may prove of value as a guide to the chemist in his search for drugs with greater curative action.

The ability of the sulfonamides to counteract certain bacterial toxins in the body has been established by Levaditi, by Carpenter and others. While it has not been possible to relate this to curative action, it is highly significant as a starting point towards drugs with antitoxic action.

Toxicity

The large doses and sustained treatment required for the sulfonamides make it predictable that toxic effects will be the rule. Are the toxic effects so closely related to therapeutic action that it will be impossible to avoid them? The answer is at present unknown, but the sketchy evidence at hand will be presented.

It appears probable, though not proved, that the more important toxic effects are related to the free amino group, which unfortunately seems essential to therapeutic activity. Aromatic amino compounds without the sulfonamide group, such as analine or acetanilid, bring about in man toxic reactions very similar to sulfanilamide, such as cyanosis, anemia, agranulocytosis, dermatitis, drug fever, nervous symptoms and liver damage. The methemoglobin formation and perhaps other of the toxic actions of acetanilid are believed to be due to oxidation products which are formed in the body. It is probable, though not established, that similar oxidation products are involved in the action of sulfanilamide on the blood pigments. At any rate, it would seem unwise to administer drugs containing an aromatic amino group (acetanilid, phenacetin, aminopyrine) to patients under sulfonamide therapy. Sulfur in the diet may increase sulfhemoglobin formation (Richardson), but this pigment is not an important factor in the cyanosis in man.

Anemia can be produced by a variety of benzol derivatives including benzol itself. Methods for quantitative study of this effect in the laboratory have recently been developed by Richardson, so that knowledge can now be obtained of the relation of chemical structure to this action. M. I. Smith of this institute has recently shown that in rats the anemia from sulfanilamide is more marked on a low protein diet; higher concentrations of the drug in the blood were present under these conditions. Fox and Ottenberg have found larger amounts of the newly described methemalbumin in the blood of patients with hemolytic anemia from sulfonamides.

The compounds in use, other than sulfanilamide, can depress renal function; this is not due entirely to the acetyl derivative, since it can occur in the dog where acetylation does not occur.

The nausea and vomiting is due, in part at least, to central action, since Sadusk could bring it about in dogs by the intravenous injection of sodium sulfapyridine.

So little is known of the mechanism of production of other toxic symptoms that it is not profitable to discuss them. It is believed that the practice of grouping many symptoms under the category of idiosyncrasy is erroneous and should be limited to such effects as angioneurotic edema or other rarely occurring anaphylactoid phenomena. The majority of toxic effects are expressions of disturbances that occur frequently, but differ widely in their severity.

Little is known concerning the role of the sulfonamide group to toxicity. The acute toxicity of sulfanilamide in laboratory animals is characterized by nervous symptoms, spasticity and ataxia, and by dyspnoea. The compound benzene sulfonamide (with no amino group) is several times as toxic to mice as sulfanilamide and brings about the same picture of intoxication.[4] The toxicity of acetyl sulfanilamide is similar to that of benzene sulfonamide, and can therefore be definitely related to the sulfonamide group.

Another effect of the sulfonamide group demonstrated by Mann and Keilin and by Locke, Main and Mellon is the inhibition of the enzyme carbonic anhydrase. This enzyme accelerates the conversion in the body of carbon dioxide into bicarbonates. By inhibiting this action the sulfonamide group brings about the so-called acidosis. The derivatives substituted in the sulfonamide group (sulfapyridine, sulfathiazol) do not show this inhibition and would not be expected to cause the acidosis. Here is an example of a toxic effect that can be abolished without loss of therapeutic action by changing the molecule. Finally it should be noted that cumulative toxicity of the sulfonamides can be demonstrated in the laboratory. Emaciation is a prominent feature and death can not be adequately explained by the lesions found at autopsy.

[4] Unpublished data.

Relation of Chemical Structure to Therapeutic Action

The development of new chemotherapeutic compounds of this class has become one of the most active fields of research. Only a few generalizations can be made concerning the several thousand compounds already described.

They are all benzene derivatives with a free or potentially free amino group in the para position to a radical which may contain sulfur, arsenic, carbon or phosphorus (Rosenthal and Bauer). Accordingly, while many changes or replacements can be made in the sulfonamide group, the amino group seems essential.

It is of interest that while some derivatives of sulfanilamide are more active against the pneumococcus and certain other organisms, none are appreciably more active against the streptococcus. It is also of interest that the sulfones, which are several times as active as sulfanilamide against the streptococcus, are only slightly more active against the pneumococcus.

Reports also indicate increased activity of the sulfones against experimental malaria (Coggeshall) and experimental tuberculosis (Feldman and Hinshaw, Smith, Emmart and Westfall). Replacement of sulfur by carbon (in p-nitrobenzoic acid) gives slight antibacterial action, and also some effect on trypanosomes. There is evidence, therefore, that specific action against certain infections can be shown.

Compounds with promising degrees of activity against streptococci have been obtained where sulfur is replaced by arsenic or phosphorus, although the former are very toxic.

These illustrations demonstrate the wide chemical approach to the problem,

and exploration of the possibilities has really just begun.

The activity of a compound is highly influenced by its behavior in the body. Many of the changes in activity reported for new compounds are undoubtedly due to such differences rather than to differences in true therapeutic activity.

Experimental Therapy

Greatly discordant results have been obtained in testing drugs upon experimental infections, and it is small wonder that in the clinic no uniformity should occur. Some factors contributing to this confusion will be enumerated.

Differences in absorption, conjugation or excretion are important, and it is to the work of Marshall[5] that a more quantitative basis has been established. Rather than the amount of drug given, he has correlated activity to the concentration of free drug in the blood. Sustained blood concentrations were accomplished by incorporating the drug in the diet of laboratory animals, after the technique of Bieter. It may be pointed out that the activity of sulfanilamide against a streptococcal infection in mice is increased more than four times if it is administered throughout twenty-four hours (in the diet) as compared to one daily dose by mouth.

The relation of diet to therapeutic response was brought out in some studies we made on mice. The blood concentration and therapeutic response was increased approximately three times on a low protein diet (6 per cent.) as compared to a normal diet. The work of M. I. Smith had previously shown that an increase in toxicity also occurs under these conditions.

Most laboratory information has been based on prophylactic therapy in the sense that medication is begun at the time of inoculation or shortly after. Delay in therapy or the use of heavy infections greatly diminishes the results. Likewise therapy of brief duration may be associated with a high percentage of delayed deaths.

Subcurative therapy may lead to the development of resistance or "fastness" to the drug by the organisms. More important is the occurrence of naturally resistant strains, about which nothing is known. Likewise the resistance to therapy of related groups of organisms, such as the alpha streptococci (viridans), is totally unexplained. Many of these naturally resistant organisms are susceptible in the test-tube.

It is of great importance to the clinician to know whether an unsatisfactory response is due to an overwhelming infection, to a resistant organism, to inadequate therapy, to difficulties in absorption or acetylation or to toxicity of the drug.

Answers to some of these problems and many new advances are to be expected from continued research in this new field.

[5] E. K. Marshall, Jr., *Bull. N. Y. Acad. Med.*, 16: 723, 1940.

THE GERMAN "RACE"

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JUST as in the case of other European nations, the origins of the Germans are lost in prehistory. The generally accepted notion is that their ancestors were derived from the Scandinavian countries. But this is probably erroneous. The large region that the Romans in the latter part of the first century B.C. found occupied by the German tribes had had, up to a certain latitude, a paleolithic, and throughout its habitable extent, a neolithic population. There is no reason to believe that the latter had completely disappeared, leaving the parts open to northern immigration.

It may justifiably be assumed that the early Germans were the descendants of the neolithic and bronze age populations of the region, with adjuncts in the course of time from what later became Denmark and from the southernmost parts of the Scandinavian peninsula. That they at any time could have constituted a "pure race" or type is highly improbable, and is gainsaid by the differences seen in the skeletal remains from the region.

There is no recorded knowledge of the new complex of people until about 350 B.C., when the first scanty information concerning them is brought south by Pytheas, a Greek trader of Massilia.

Between 113 and 102 B.C. the Germanic tribes of Teutoni, under chief Teutobod, and Cimbri, carry out a mass trek southward with their families, wagons and animals, over the Rhinelands and through what is now France, towards Italy, but are almost annihilated at Aquae Sextiae (now Aix-les-Bains) by the Gallo-Romans under Marius and disappear from the stage.

The terms *Germania* and *Germani* appear first in a writing of the Greek historian Posidonius, in 80 B.C. Their derivation is uncertain. It is believed that they were first employed by the Gauls, for their non-gallic neighbors beyond the Rhine. It was not used by the earlier Germans, and to this day is among them of secondary nature. It was definitely established by Caesar, in his classic "De bello Gallico." The terms *Deutsch* and *Deutschland*, by which the Germans call themselves and their country, are derived (Brockhaus) from *diot*, the People, and came into use much later, appearing first towards the end of the ninth century in Italy, and rarely in Germany until the end of the thirteenth century. The term *Teutons*, as applied to all the Germans, is also late, beginning to appear from about the middle of the tenth century.

For the first three centuries of our era —centuries of direct contacts of the Romans with the Germans—information about the latter is limited to Roman and Greek historians, the most prominent among whom are Strabo,[1] Pliny the Elder,[2] Tacitus[3] and Ptolemy.[4] But only a part of this information is first hand, the rest being derived from the reports of traders and soldiers; and none is exhaustive.

It is known then, however, that the Germans are a relatively large group; that they consist of numerous independently warlike tribes, which though apparented in blood, differ more or less in language and in other respects; and that these tribes occupy most of the large region bounded by the Rhine, the Dan-

[1] Geography; around the beginning of the Christian era.

[2] Bella Germaniae; Natural History, third quarter of first century A.D.

[3] Germania, 98 A.D.

[4] Geography; latter half of second century A.D.

ube and the northern seas. The eastern boundary alone, and that both geographically and ethnically, was indefinite, the Germans impinging there on an even much less known people, the "Venedi" or, as later known, "Sclaveni," or Slavs.

The Roman wars and contacts with the Germans lasted from the middle of the first century B.C. to the fourth century A.D. These contacts were especially close in the Rhine provinces, where the Romans founded a line of cities and where they doubtless had left among both the Gauls and the Germans some blood admixture. The Gauls and Germans, alone, bordering since old on each other and overlapping in places, must also have mixed and that apparently to a considerable extent, somatic evidences of which exist to this day in these parts, as will be shown later.

The German tribes were sturdy and prolific; the people, except along the seas, were essentially agricultural; but large parts of the territory they occupied were covered with forests or sands that gave little sustenance and had harsh climate. The results were, as already seen with the Teutons and Cimbri, mass movements in all promising directions, particularly towards the warmer and richer lands in the south; and as all these regions were occupied, the German spreads became for the most part forcible invasions.

These invasions began, so far as recorded, towards the end of the second century B.C. by the already mentioned Teutons and Cimbri, are followed in the first half of the second century A.D., in the east, by that of the Vandals, though there is doubt as to the Germanic affiliation of this group; towards the end of the second century by that of the Goths, who were, it seems, of Scandinavian derivation; and in the fourth to fifth centuries, when Roman domination weakened, by those of the western coast tribes (Angli, Saxons, etc.) into Britain, the Franks into Gaul (present Belgium and France), the Burgundians[5] into Gaul, the Alemans[6] and Suevi (Swabians) into Switzerland, the Langobards towards the middle Danube and finally Italy. None of these offshoots return to their former abodes; but some stay in parts that eventually become southern Germany and there admix with the older Gallic or Keltic populations.

To this time there is no union or even a close association of the numerous Germanic tribes; but by the fifth century the Franks have established their dominion in "Gallia," accepted Christianity, subject gradually the Alemans, Thuringians, Bavarians and Frisians, under Charlemagne (768–814) also the Saxons, and effect the first union of the Germanic tribes. In 843 the great Frank dominion by the treaty of Verdun is divided into three parts, and that is the political beginning of both France and Germany.

Meanwhile important developments of other nature are taking place in the eastern parts of the territory that eventually will be comprised by Germany.

The main region of the early Germanic tribes lay west and southwest of the Saale and Elbe Rivers. To the east and northeast of this territory lay extensive lands, hilly in the south, sloping towards the north and terminating in vast flats. All these parts, up to the Vistula River, more than twice as large as the Germany proper, were represented by Tacitus and other early historians as belonging to "Germania," though the knowledge of them until long after was very hazy, and the concept of the "German" people was far less crystallized than it is to-day. It is impossible to cover this great region with any known German tribes. The prevalent notion,

[5] There is still the province of Burgundy in western France.

[6] The French name for Germans is to this day "les Allemans."

held especially by German writers, is that the region was vacated by Germanic peoples. But, even if all the more eastern Germanic or Scandinavian groups that moved southward from the first century onward could be attributed to it—which it seems they can not—the territory could still nowhere near be filled, even in its more favorable parts for human occupation. Here is a serious unnatural void of which no one has given as yet a plausible explanation.

As history begins to unfold, however, this great expanse is found filled, even if not thickly, by non-Germanic elements. There are the *Aesti*—undoubtedly the old Lithuanians—in what is now Eastern Prussia; and the rest is filled with the large group of *Lugii*, which name is evidently of Slavic derivation (*lug, luh* = field, meadow), and with many tribes of Slavs. These are assumed to have spread over the country from beyond the Vistula after the Germans moved out. This assumption is unsatisfactory. If the Slavs moved in and stayed, then the country could not have been worthless and would not have been abandoned by its older inhabitants. Nor were the Slavs of the time as well armed as the Germans so that they would have been able to drive the latter out, besides which there is no mention anywhere of such a major event, which would have caused as great disturbances, at least, as the Hunnish invasion in 375 of the Goth territories further southeast.

The *Venedi* (Slavs) are first mentioned, in the first century A.D., by Pliny and then by Tacitus, but these notes are scant, not based on original observations and indefinite. Ptolemy, in the latter half of the second century, while still not original and in many respects in error, gives more information. He knew of the Venedi now as a "megiston ethnos," a great population, whom on his map he places along the Baltic and the "kolpos Venedinus" (Venedic Bay), to the east of the Vistula River, and in "Sarmatia," placed in present Poland. By the end of the sixth century they are already generally known of, and found to occupy almost the whole great region from what are now southeastern Denmark and Pomerania, to the right of the Elbe and Saale Rivers, and to the southern boundaries of Bohemia and Moravia. "By the end of the sixth century the whole basin of the Elbe, except the Saxon territory near the mouth, had probably become Slavonic" (Latham; Encycl. Britan., XI. ed.; et al.).

The term *Slavs*, or Sclaveni, like that of "Germans," is not an original generic name of the Slav people, as was not that of the Wends or Winds or Venedi. The latter terms were applied at first to only the Baltic Slavs, but came eventually to be used for all their neighbor Slavs by the Germans. Their origin is unknown. The name "Slavs" is believed by many to have been derived from "slovo," the word, but proceeds more probably from the extolling affix "slav" (from slava, glory), used in many of the personal Slav names in early times and occasionally even now. It occurs in both Procopius and Jordanes, the principal historians of the sixth century. Both the names, Vends and Slavs, extended to many tribes related by blood and language, but, as is true of the early Germans, not united and practically independent of each other. Linguistically the stock belonged to the Aryan family of languages, being related most closely to the Lettish and next to the German. Physically they were, according to reliable indications, predominantly light-haired, medium-statured, sturdy people, originally probably mostly of oblong head, differing but little from the central Germans. They were essentially agricultural people, lived in numerous characteristic villages, but had also some cities and famed sanctuaries. Their cradle was the great

region north of the Carpathians, from the watershed of the Vistula to the Dnieper River. They were "pagans," with a religion related in general to the Greek, and recognized one chief deity. They were not militarily as developed as the Germans or Romans, but were sturdy fighters. In their ever recurring struggles with the Germans in the west and the eastern Roman empire in the east they both took and lost many prisoners—men, women and children—which in time served to admix both of the contending sides.

German historical literature, even though largely biased, and also the Danish, are full of testimonies about the Slavs of the eastern portion of Germany and their gradual absorption. This absorption of the ununited Slav populations continued systematically and often forcibly from the time of Charlemagne in the latter part of the eighth to beyond the fifteenth century, without to this day being completed or ended. The principal means were domination, colonization and Christianization. The process, as now, was mainly "by the sword and the fire"—"ferro et igni vastavit" (old reports). And it was not uniformly successful. Toward the end of the tenth century "the Slavs fought with such courage and success that during the reigns of the emperors Otto II and Otto III much of the work effected by the Margraves Billung and Gero was undone, and nearly two centuries passed before they were driven back to the position which they had perforce occupied under Otto the Great." (Enc. Br., XI ed.) In 983 a particularly great Slav revolt stopped the Germanization and this could not recommence until the middle of the twelfth century. "By that time were Germanized only the Main and Rednitz Slavs with those of the lands between the Saale and Elbe." (Gr. Brockhaus).[7]

The testimonials of the absorption into the "German" stock of the large mass of western Slavs are a legion and it is not necessary to search for them outside of German sources alone.

In the twelfth century the Danish kings used also the title "kings of Slavs." Pomerania, the large northern province of present Germany, was wholly Slavonian until well after the middle of our era. In the words of Latham ('51, p. xvii), "Adam of Bremen first mentions these Pomeranians, and he mentions them as Slavonians, the Oder being their boundary to the west. On the east they were conterminous with the Prussians. Their name is Slavonic *po*—on and *more*—sea, *i.e.*, coastmen. All their antiquities and traditions are equally so; in other words there is neither evidence, nor shadow of evidence, of their even having dispossessed an older Germanic population. Nor are they wholly extinct at the present moment." And there are almost endless accounts of and references to the Slavs of the other parts of present east Germany. There are in the German language numerous names relating to agriculture and various old industries that were taken from the Slav. The famed association of trading cities "Hanza" is attested to have been based on Slav trading establishments. A great number of the names of cities, villages, rivers, places, all over the former territory of the Germanized Slavs, are Slav names or corruptions, which would surely have disappeared had their Slav population been driven out or annihilated. The very name of the chief deity of the northern pagan Germans, Wotan, Wo-

[7] "Um die Mitte des 12 Jahrh. hatte die Unterwerfung der Slawen an Havel, Elbe und Oder begonnen, vor allem durch Albrecht den Bären, der die alte Nordmark zur Mark Brandenburg erweiterte, und durch Heinrich den Löwen; nach dessen Sturz wurden die slawischen Fürsten in Mecklenburg und Pommern selbst reich-unmittelbare Herzöge. . . . Schlesien wurde auf dem Wege der friedlichen Germanizierung allmählich für Deutschland gewonnen." (Brockhaus, IV, 677).

dan, Woden or Odin—may possibly be of Slavic derivation.

Perhaps the most interesting survival of the Slav times in eastern Germany is the name of Berlin, the capital. This name is a corruption of Barliň, an old Slav fishing settlement on the right bank of the Sprewa River. Opposite this, on the left bank, was the Slav town or village of Kolin. The first settlement of Germans is introduced here about 1144, under Albrecht the Bear, who thus began the Germanization of the place. The two settlements on the river were united in 1307; between 1373 and 1415, they with the district belonged to the Czech crown; in the Thirty-Years War the inhabitants were reduced to 6,000; in 1442 Friedrich II built here a strong castle, and from that time on the now rapidly growing place was "Berlin," first the provincial and finally the empire capital.[8]

Rostock is the old Slav Rostok (spread of the river); Lübeck is a twelfth century corruption of Liubice, a local Slav village; Breslau up to 1241 was Vratislav, a seat of a Polish dukedom of the same name, and from 1335 to 1742 belonged to the Czech crown; Leipzig was the old Serb town of Lipsko, mentioned also as Lipzk, Lipzek, Lipzik, from which since the fifteenth century the "German" Leypzik to present Leipzig was derived. And the list can be much extended. Many of the family names of the eastern larger half of present Germany also are Slavic or easily recognizable corruptions.

Besides the Slavs, the Germans, since the twelfth century, have incorporated with themselves and Germanized also other eastern populations. The chief of these were the Birussians or "Prussians," a branch of the old Lithuanians, living in parts of what is now Eastern Prussia. The forcible subjection of the tribe, once more "by the sword and fire" and under the guise of Christianization, was carried out between 1232 and 1283 by the Order of the German Knights. The Birussians were largely annihilated, German colonists were settled in the country and the German Reich was enriched by a new province. Ironically the names of "Prussia" and "Prussians" stayed, spread to "western Prussia," and finally became those of the large dominant and most militant parts of the German realm and people.

Slowly advancing has also been and is now the Germanization and absorption of the Slavs of western Poland. A forcible process, such as affected the Birusi, was tried by the same Order of the German Knights, but the Poles proved too strong and the effort came to an end in 1410 at the battle of Grünwald, from the effects of which the Order never recovered. However, the three divisions of Poland, 1772, 1793 and 1795, between Prussia, Austria and Russia, opened once more the door to Germanization, especially of Poznaň (Posen) and the Baltic part of the country, and this proceeded until the First World War, at the end of which the former western boundary of Poland was restored. From 1772 to 1918, however, many of the western Poles were assimilated into the German mass, introducing thus further Slav admixture.

Since the early parts of the second millennium of the Christian era and up to the 1914–1918 war, slow but constant and strenuous efforts were carried on also at Germanization of the desirable Bohemia and Moravia. German artisans, traders and colonists occupied gradually parts of both lands, were favored in every way at the expense of the Slav population, and every agency, including again the "sword and fire," were used; but with little final success. The "sword," domination, systematic forced colonization, are once more in full action, and the fate of Lidice has shown

[8] G. Langenscheidt, Naturgeschichte der Berliner; Ottos (Czech) Encycl.; etc.

that "fire" is only awaiting its turn. Still worse action is taking place in Poland and in the occupied Baltic and Russian provinces. The German blood needs more Slav "fertilizer," as cynically acknowledged on occasions.

SOUTHERN ADMIXTURE

Long before the Germans impinged on the western Slavs—or long at least before this is recorded—they came into contact with the Gallic or Keltic peoples in the south. These, while equally a part of the great White Stem, belonged to the "Alpine" or mid-European race. They were of darker hair and eye pigmentation, robust and well built, in general of medium stature. They originally occupied and were evidently indigenous to the great Alpine region from the middle Danube westward, covering the old Rhaetia (Austria-Tirol), Bavaria, with present Württemburg, Baden, Palatinate, Rhineland and Alsace-Lorraine, Helvetia (Switzerland), Gaul (France and Belgium) and also parts of Britain with Ireland. Just when the Germans came into contact with these is not known—it must have been well before the advent of the Romans, for by that time all serious violence had ceased and the people of what became the southern German states already spoke German. There are known, however, the later influxes of the Alemani, Marcomani and Suabi, and later those of the Franks, Burgundians and other tribes, and as far as these affected lands now united into "Germany" they represented so many agencies of admixture. The results of all this was a greater or lesser fusion of the more northern elements with the Alpines, leaving a mixed population. The amount of this southern miscegenation was probably not incomparable with that of the Slavs in the east, and each may perhaps roughly be estimated at about one third of the resulting "German" body.

ADDITIONAL ADMIXTURES

In the course of time the original Germanic tribes received additional minor admixture of heterogeneous units. There were the Borussian or Lithuanian accretions in the northeast, some mongoloid blood during the large Asiatic invasions, before these some Mediterranean infusion during the Roman wars, Dutch and Scandinavian elements, and finally, in the course of centuries, some Jewish accession. None of these were of much moment; nevertheless together they added to the admixture of the original more "nordic" Germans.

Most of this miscellaneous mixture took place in the larger cities, and not seldom was invited or favored. Thus we read in the histories of Berlin that from the fifteenth century on it welcomed many newcomers and refugees, from Switzerland, Italy, France, Bohemia, Holland and other countries. According to Langenscheidt the modern Berlin is regarded as "a German-speaking neutrum," and holds approximately 39 per cent. of French, Belgian and Italian elements, 37 per cent. of German and 24 per cent. of Slav.

PHYSICAL EVIDENCE

Strangely, though the Germans before the first World War stood in the foreranks of science, including anthropology, the people of Germany have never been thoroughly studied and so the somatic picture of them is still incomplete. This is hard to explain, unless it be attributed to a disinclination to show both to themselves and to others how really far from homogeneous is the German nation.

There were nevertheless more or less limited studies that indicated the conditions. At the head of these stands the survey in the seventies of the last century, by the teachers of public schools, of nearly seven million of the school children of the country. This survey

was carried out under the auspices of the Berlin Anthropological Society, and the results were reported in 1876,[9] and especially in 1885, by Rudolf Virchow.[10]

The total number of children examined was 6,758,827 from all parts of the empire, of which 75,377 (1.1 per cent.) were Jewish. They ranged from six years to high-school age, a very large proportion being below 14. Noted, under instructions from the society, were only the color of the hair, eyes and skin. Though the pigmentation of the hair has not yet reached its final stage—the hair in general darkens progressively until well in the adult stage—the results showed that there was far from any general blondness or any uniformity between the different parts of Germany. The main results for the 6,758,827 children examined were as follows:

Type	*Per cent.*	*Hair*[11]	*Per cent.*
Blond	31.80	Blond	68.02
Brunette	14.05	Brown	29.42
Mixed	54.15	Black	1.98
		Red	0.25
Eyes		*Skin*	
Blue	39.55	Light	91.50
Brown	27.21	Brownish	8.45
Grey	33.18		

Jewish children showed throughout darker. The territorial distribution of types were:

	Blonde	*Brunette*
Northern	33.56 per cent.	11.17 per cent.
Central	25.29 " "	14.74 " "
Southern	18.44 " "	25.21 " "

The blonde type ranged from 9 per cent. in a locality in south Germany to 56 per cent. in part of Oldenburg. In the left Rhine zone (Alsace, Lorraine, Palatinate) it was but 16 to 18 per cent. In parts of Oberpfalz and much of Bavaria the blonds were reduced to 9–14 per cent. In individual districts the brunette type ranged from four per cent. in a part of Oldenburg to 91 per cent. in a part of southern Germany. The "mixed forms" were recorded as 40 to 69 per cent. of those examined in different localities.

The mixed nature of the German people is fairly acknowledged by the author (Virchow). Thus, on p. 323, he says: "The results convey the view of a marked *southern zone of mixture, which extends through Germany in south-north direction*"; p. 324: "There is a multitude of mixed forms"; and, p. 326: "It is surely very remarkable that *exactly one-third of all German school-children have grey eyes.*"

The whole showing of this highly valuable survey demonstrated clearly, though still incompletely, the mixed nature of the German population. Incompletely, because many of the Slavs were as light-haired and all as light-skinned as the Germans, so that their admixture could not show in a study of this nature.

The German Skull

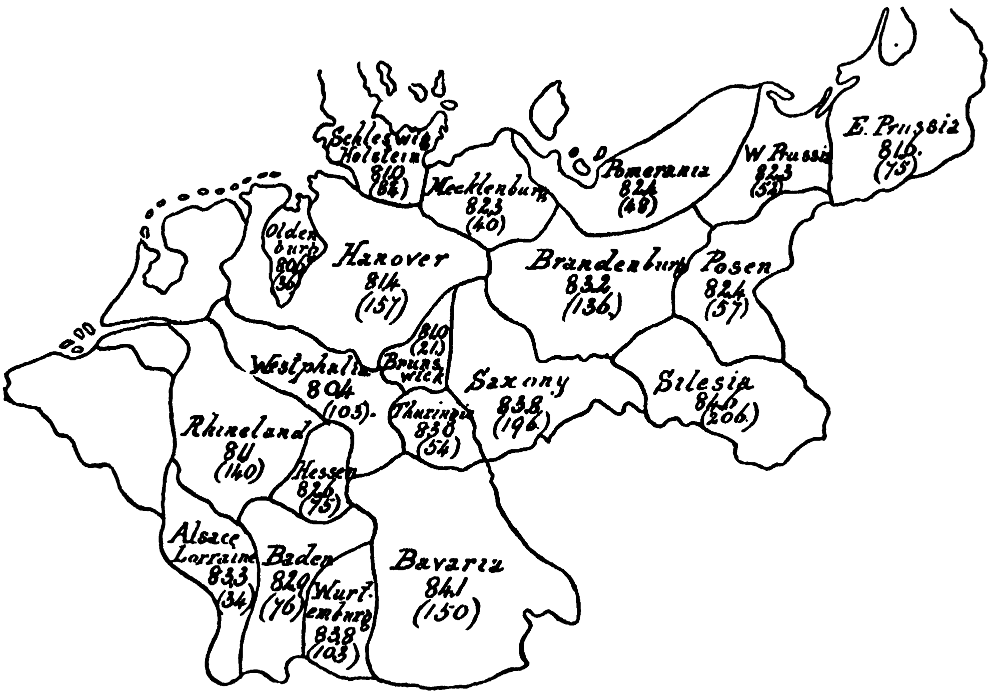
There are many contributions in German to the knowledge of the German-territory skulls, but a definite collective and unbiased work on the subject is still wanting. Some of the main studies are noted below,[12] and they give references

[9] Beiträge zur physischen Anthropologie der Deutschen. *Abh. k. Akad. Wiss.*, Berlin, (1876) 1877, 11 *et seq.* And *Verhandl. Berl. Ges. Anthrop.* etc., 1876, 16–18.

[10] Gesammtbericht über die von der deutschen anthropologischen Gesellschaft veranlassten Erhebungen über die Farbe der Haut, der Haare und der Augen der Schulkinder in Deutschland. *Arch Anthrop.*, XVI, 1885–6, 275–475.

[11] As light hair generally darkens more or less with age, the proportion of lights in adults would be considerably smaller and that of the darks larger.

[12] Crania Germaniae. Freiburg, 1865 (various workers); J. Ranke, 1880—Die Schädel der altbayrischen Landbevölkerung. Beitr. Anthrop. Urgeschichte Bayerns, III, 108–205; J. Kollman, 1881—Beiträge zu einer Kraniologie der europäischen Völker. Arch. Anthrop., XIII, 179–232; Katalog der anthropologischen Sammlungen Deutschlands. Publ. by various workers in the 80's and 90's of last century; A. Schlitz, 1910—Die vorgeschichtlichen Schädeltypen der



CEPHALIC INDICES IN THE VARIOUS PROVINCES OF GERMANY

to others. Data on the subject in English are scarce and scattered.[13]

The evidence may be summarized briefly. As with pigmentation, the German skulls vary greatly according to locality. The cranial ("cephalic") index ranges from low dolicho- to the highest brachycrany. There are long and short, high and low skulls, small and large. In general the southern German lands, Bavaria, Baden, Alsace, with their neighboring regions, show a predominance of the short and broad Alpine type of the skull, while in the northwestern parts the skull is more commonly oblong, approaching a similar type in the Scandinavian countries. Even in the old row-burials, however, which are regarded as particularly characteristic of the protohistoric Germans, the skull type already differed, as did also stature and other features.[14]

Present Head Form

Among the living Germans, oblong heads, and hence skulls, which are claimed as the true German, are in general much less frequent than the broad and short or brachycephalic. This is a matter of common observation, but also of some independent scientific researches.

During the first World War anthro-

deutschen Länder. Arch. Anthrop., IX, 202–251; E. Hug, 1940—Die Schädel der frühmittelalterlichen Gräber aus dem solothurnischen Aaregebiet in ihrer Stellung zur Reihengräberbevölkerung Mitteleuropas. Z. Morphol. & Anthrop., XXXVIII, H.E., 359–528; w. Bibliog.

[13] For a spirited chapter on the whole subject of germanism and physical anthropology see W. Z. Ripley's "The Races of Europe," N. Y., 1899, 213 *et. seq.*

[14] An especially explicit note on the subject is found in Walther Kruse's large work on "Die Deutschen und ihre Nachbarvölker," 8vo, Leipzig, 1929, p. 220: "Wie wir gegenüber Schliz ganz bestimmt versichern können, zeigen auch die altslawischen Schädel *in allen eben besprochenen Punkten keine characteristischen Vershiedenheiten von den germanischen.*" (Ital. in orig.).

pological measurements were taken by Parsons and Le Gros Clarke on respectively 925 and 840, or in all, 1,765 prisoners of war, coming from all parts of Germany.[15] The average cephalic index of the group was 82.5, or plainly brachycephalic; and it ranged, according to the provinces, from 80.4 in Westphalia and close to 81.0 in the western regions, to 84.1 in Bavaria and 84.6 in Silesia.

Even in the most blond Oldenburg it was 80.6, or low brachycephalic. The results are shown in the accompanying map of Dr. Parsons. In his words, "The most striking lesson is that nowhere in Germany of today could I find material with a cephalic index below 80." An index from 75 to 80 denotes, as is well known, mesocephaly, which prevails both in England and in the old American stock; and only below 75 commences dolichocephaly. It is true that in the skulls the German indices would be about 1.5 points lower, but this would make only little difference. The final conclusions of Parsons is that "the prisoners at our disposal give us no reason for thinking that there is any part of modern Germany in which the Alpine or Slav characteristics have not dominated the Teutonic or Nordic."

Parsons and Clarke have also observed the pigmentation of the hair and eyes in 3,350 of the German prisoners, and the results show in the various provinces of from 10 (Hanover, Mecklenburg) to 37 (Alsace) per cent. of "pure brunettes,"[16] which does not differ very materially from the results obtained by the previously dealt with survey of German school children.

Parsons records also the measurements of stature of 1,545 subjects. The means ranged from 5′ 6.1″ in Württemburg and Bavaria to 5′ 8.1″ in Mecklenburg—once more substantial differences.

[15] F. G. Parsons, Anthropological Observations on German Prisoners of War. J. Anthrop. Inst., Lond., 1919, XLIX, 20–35.

[16] Those in whom dark to black hair was accompanied by brown eyes.

German Immigrants

The second and independent series of measurements on adult Germans were taken under my direction by Dr. Mary T. Mernin, on Ellis Island, the New York gate for immigration. They extended to 100 normal but otherwise unselected males 24–58 years of age, and the measurements were taken with especial care so that they might safely be used for scientific comparisons. The men came from various parts of Germany and close to 90 per cent. bore strictly German names. The average stature of these men was 170.4 cm (5 ft. 7 in.), but ranged from 156.1 to 186.2 cm. The mean cephalic index of the 100 was *83.15*, with the range from 70.6 to 93.3, or from dolicho- to hyperbrachycephaly.

Some exceedingly interesting comparisons are now possible with an equal-sized series of incoming Frenchmen, measurements on which were taken at Ellis Island by the same person as well as methods and during the same period. Here too the subjects came from various parts of France and come probably close to representing the general average status of the population. It will be of advantage to contrast in this case all the determinations and to compare the same also with those obtained on Old Americans.[17]

The statural and also the absolute weight in the Germans are slightly higher than they are in the French, both being lower than the Americans; but proportionately to stature the French are slightly superior in weight to the Germans.

In the arm-spread both the French and the Germans show some excess over the Old Americans—their arms are relatively somewhat longer.

In the height sitting the Germans show slightly the highest, with the French close next, and the Americans close last.

All through these several determina-

[17] A. Hrdlička, "The Old Americans." Baltimore, 1925.

TABLE 1

MEASUREMENTS OF GERMAN, FRENCH AND AMERICAN ADULTS
Average Weight and Stature in Metric Units

Group	Subjects	Ave. age yr.	Stature cm.	Weight kg.	Weight: grams per cm. stat.	Arm-spread per cent. of stature	Height sitting per cent. stature
Germans	100	30.5 (24–58)	170.4	67.5	87.3	104.3	53.3
French	100	30.0 (24 58)	168.8	67.0	87.6	104.9	53.1
Old Americans[18]	250	42.5 (24–60)	174.5	68.2	86.2	102.7	52.9

tions the Germans and French are closer together than either of them is to the Old Americans.

The head of the Germans is the broadest and shortest giving the highest cephalic index (Table 2). The French of our series give actually appreciably lower index than the Germans.

In the height of the vault the Germans and the French are again considerably alike with the Americans above both of them.

The size of the head is absolutely greatest in the Old Americans, with the Germans and French closely alike. Relative to stature the French head shows slightly the best, the German close second, the American last (due to the elevated stature).

The facial dimensions are practically the same in the Germans and the French, but the face is narrower in the Old Americans. All this is reflected in the indices (Table 3).

The forehead is slightly the lowest in the French, due to slightly lower descent of the hair. In breadth it is a trace narrower in the Americans, in correlation with the lesser breadth of the vault.

The breadth of the lower jaw at its angles is the same in the Germans and the Americans, slightly greater in the French.

Once more there are astonishingly close relations between the Germans and the French.

TABLE 2

HEAD

Group	Length cm.	Breadth cm.	Height[19] cm.	Mean head diam. cm.	Mean head diam. vs. stature	Cephalic index	Mean height index
Germans	19.1	15.9	13.6	16.19	95.0	83.1	77.5
French	19.2	15.7	13.5	16 14	95.6	81.7	77.2
Old Americans	19.8	15.5	13.9	16 40	94.0	78.3	79.0

TABLE 3

FACE

Group	Total height—hair line	Height to nasion	Greatest breadth	Facial index total	Facial index, lower	Height of forehead[20]	Smallest breadth of forehead	Lower jaw breadth at angle
Germans	18.3	11.8	14.2	77 5	83 1	6.57	10.8	10.6
French	18 3	11.9	14.2	77 3	83.8	6 34	10.7	10.8
Old Americans ..	18.5	11.9	13.9	75.1	86.1	6 58	10.6	10.6

[18] Laboratory series.

[19] See writer's "Anthropometry," Philadelphia, 1920, '39.

[20] Where unaffected by loss of hair.

TABLE 4

Group	Nose Height	Nose Breadth	Nose Index	Left Ear Height	Left Ear Breadth	Left Ear Index
Germans ..	5.45	3.56	65.3	6.46	3.72	57.6
French ...	5.43	3.62	66.6	6.46	3.85	59.6
Old Americans	5.35	3.61	67.5	6.69	3.79	56.7

The nose and also the ear show close similarities in the three groups. The slightly relatively broader nose in the Americans is connected with the greater average age of the Americans.

The somewhat marked excess in ear length in the American group is doubtless due also to the higher average age. The French ear is slightly the broadest, but its height is identical with that of the Germans.

TABLE 5

CHEST (AT HEIGHT OF NIPPLES)

Group	Breadth	Depth	Index
Germans	29.7	21.4	72.2
French	30.4	22.3	73.2
Old Americans ...	29.8	21.7	72.9

The chest shows slightly the best in the French, particularly in relation to stature, but the differences are small (Table 5). The chest index too is much alike in the three groups.

TABLE 6

Group	Left Hand Length	Left Hand Breadth	Left Hand Index	Left Foot Length	Left Foot Breadth	Left Foot Index
Germans ..	19.3	9.3	48.5	26.6	10.2	38.3
French ...	19.35	9.4	48.4	26.4	10.0	37.8
Old Americans	19.3	9.2	47.6	26.1	9.5	36.3

The hand and foot are almost identical in the Germans and the French, somewhat narrower in the Americans (Table 6).

TABLE 7

STRENGTH IN HANDS

Group	Pressure (in kg.)[21] Right hand	Pressure (in kg.)[21] Left hand	Traction (bimanual)
Germans	39.7	37.3	20.1
French	39.1	37.2	21.4
Old Americans ..	41.8	36.1	22.3

[21] With Mathieu and Colin dynamometer.

In the strength of the hands, both pressure and traction, the Germans and French are again very much alike, and both are close to the Americans, in whom however the disproportion between the right and the left hand is somewhat greater (Table 7).

In this connection it may be said that while the Old Americans stand somewhat apart, the Germans show so many and so close similarities with the French that no closer relations could be expected between any two like groups of Germans themselves. This is, of course, only in the averages which cover a multitude of variance.

But such averages are of very much value in general comparisons. They show plainly in this case how unfounded are all efforts at any segregation of the German "race."

CONCLUSIONS

There is a German nation, a large linguistic and political unit.

This nation originated in what are now northwestern and western Germany north of the Rhine, from the prehistoric occupants of these regions.

There are indications that the main old stock of these parts was related to the principal stock which in the early neolithic times peopled the Scandinavian countries, but from old showed some heterogeneity.

From prehistoric times to the present day the German people, always strong in numbers as well as in armaments, partly peaceably but largely by force,

have been absorbing their neighbors, the Kelts in the south, the Slavs and in smaller measure the Lithuanians in the east; and the progeny of these accretions admixed more or less the former parts of the nation.

The additions to the old German stock were collectively so numerous that in general they greatly modified the same in pigmentation, head form and general physique.

The Germans to-day are a major complex of Germanic-Keltic-Slav composition, and different basically neither in language nor any special physical or even inborn mental characteristic from other white people. They have become what they are to-day, aside from education, through tradition, habits and especially indoctrination.

Racial pride, while not inborn, is, wherever conditions permit, a universal part of both our idealism and egoism, and within bounds is a potential agency for much that is beneficial. But if not held within wholesome limits or if fanned by the demagogue for his own designs, it may readily pass into conceit, arrogance and strife.

There has never been nor is there now any nation of any accomplishments that did not regard itself as superior, in the line of those accomplishments at least, to others. Where the accomplishments alone do not suffice it will draw upon fabled descent, with overexalted ancestors. And woe to realities and even good common sense where there is some justification for the self-esteem. In that case facts of any kind that disturb must give way. They are colored differently, or roughly denied and passed over. "Racism" is a psychological phenomenon, but may be made into a powerful agency for temporary unity of a people and its following of self-imposed leaders.

HIGHER EDUCATION IN CHINA

By Dr. ZING YANG KUO

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In 1912, when the Chinese Republic was established, there were only four institutions of higher learning with a total number of students below five hundred (461) and with an annual expenditure of $755,730 Chinese currency, according to a recent report by the Ministry of Education of the Chinese National Government. By the time when the war began in 1937, the total number of universities and colleges in China had increased to 108, with a total enrolment of 31,188 students. The annual budget for higher education for the year 1937 was $35,574,896 Chinese currency. The rapid progress and expansion of higher education in China during the twenty-five years previous to the war are clearly indicated by these figures. But the improvement in the quality of teaching in universities and colleges is even greater than the increase in the number of schools and students.

During the last four years, the Japanese army and air forces have been deliberately and systematically destroying Chinese educational and cultural institutions. Those located in the areas occupied by the Japanese troops have been plundered or forced to discontinue their work, while those situated behind the Chinese lines have been systematically sought out and bombed from the air. Of the 108 universities and colleges and technical schools at the outbreak of hostilities, fourteen were totally destroyed, while eighteen were damaged to such an extent that it has been impossible to

operate them. Seventy-three other institutions which were removed to the interior can not utilize the equipment they originally had and are operating on very scanty resources. The total losses of property sustained by the Chinese universities and colleges as a result of the war have been estimated at $65,200,000 Chinese currency. The total losses of books are well over ten million volumes.

In spite of the great losses and destruction, the Chinese universities and colleges are still operating on a more or less regular schedule. At present there are 104 universities, colleges and technical schools operating on a regular schedule. Most of these schools have been removed to the interior. Of these 104 institutions of higher learning, 13 are mission colleges, which are operated by missionaries and supported partly by the churches in the U. S. and partly by tuition fees and subsidies from the Ministry of Education of the Chinese Government. Of the some 50,000 students now studying in Chinese universities and colleges, about 7,000 are enrolled in the mission colleges.

The war has not only not diminished the number of students, but has increased it. As noted before, the total number of students at the beginning of the war was 31,188. It was increased to 36,180 in 1938 and to 44,442 in 1939. At present, it is well over 50,000. A great number of these students have come from the areas occupied by the Japanese troops. Many of them had traveled mostly on foot more than one thousand miles to receive their college education in Free China.

While Chinese universities and colleges are still able to maintain their work in spite of the extreme physical hardships which teachers and students have been enduring during the last four years, their suffering from what may be described as "intellectual starvation" is the most unbearable. In a great many cases, both teachers and students are working without library or laboratory facilities. Teachers would lecture from memory or use old textbooks. Students generally work with bare hands, taking down lecture notes with scanty opportunity for collateral reading in the library or for experiments in the laboratory. A great many teachers of science have not seen a single copy of scientific periodicals for more than three years. Under such conditions, it is almost impossible in a great many cases to carry out scientific research except in a very primitive manner. Consequently, there has been a decided downward tendency of the intellectual level among the Chinese colleges and universities despite the fact that the number of students has steadily increased and that class exercises have been regularly maintained.

While China is still at war against an aggressor nation, her educational leaders have already begun to plan for the rebuilding of her culture and education. The work of educational and cultural reconstruction will be started as soon as the war is over, or even sooner, if sufficient assistance and cooperation from the United States can be secured. In fact, while China is fighting for her national existence, she is at the same time remaking the nation. Education occupies a very important part in her program of national reconstruction.

In order to appreciate the importance of China's new program for reconstruction of higher education, the following existing conditions in China upon which the new program is based should be briefly stated:

The war has offered China an excellent opportunity for a long range planning for her national reconstruction. In industry and agriculture, China has already undergone tremendous changes since the outbreak of the war. The time seems to have arrived when China should start her national planning for economic

reconstruction so as to avoid the evils of capitalism and Nazism and the mistakes of Communism. In such a national planning, education—especially higher education—should be included as a most vital part of the new national structure. In planning a new program for her higher education, therefore, great stress should be laid on the training of scientific and technical personnel for national economic reconstruction so that when the economic reconstruction begins, there will be an adequate supply of trained men for various tasks. However, other aspects of cultural studies such as arts, philosophy, literature and humanities, etc., will not be neglected.

At present, there is already a great shortage of trained personnel in various fields, especially in science and technology. When the war is over and reconstruction in industry and agriculture is begun, the shortage of personnel will be very much more acute unless a well-planned program for training men and women for the tasks of reconstruction is worked out well in advance.

At present, most of the university professors in China and most of those who hold important positions in government and in industry were educated in foreign countries, particularly in the United States. Due to the lack of library and laboratory facilities and other resources and to the insufficient number of first grade professors in China, the training of scientific and technical personnel for cultural and economic reconstruction in China will depend, more than ever before, upon sending students to study in the United States and upon inviting American scholars to teach in Chinese universities. Unfortunately, since the outbreak of the war, the number of Chinese students studying in this country has decreased considerably. Arrangements must soon be made so that greater numbers of Chinese students can be sent to this country for scientific and technical training if the program for the reconstruction of China is to be carried out in due time.

During the last thirty or forty years, the Chinese Government had adopted a laissez-faire policy with regard to Chinese students studying abroad, with the result that a great many students did not acquire their training according to the need of the nation and were unaware of those specific and unique problems with which they would be confronted when they returned to China. Consequently, such students often found themselves ill-prepared and unequal to their tasks when they were required to deal with such problems.

The New Program for Reconstruction of Higher Education

Based upon the above facts and conditions, a new program for reconstruction of higher education in China has been evolved. It may be briefly outlined as follows:

1. A long range national program for the development of higher education during the next fifteen or twenty years is to be laid out.
2. This program will be based upon and coordinated with economic reconstruction of the nation.
3. A nation-wide survey is to be made to ascertain the number and kinds of scientific, technical and professional personnel which will be needed during the next fifteen or twenty years for industry, government services and for teaching in universities and colleges. Based upon this survey, the number of graduate students to be trained each year in China and in the United States will be determined.
4. Every effort will be made to discourage establishment of new universities or colleges and to close down those which fail to comply with required academic standards. Unnecessary duplica-

tions in instruction and research are also to be discouraged and reduced to a minimum.

5. Although at present there are still 104 universities and colleges in operation, in view of the lack of adequate teaching staff and resources, we shall not attempt to re-equip all of them and bring them all up-to-date. On the contrary, we shall select only four or five out of these 104 institutions and concentrate our efforts on rebuilding them, bringing them up to modern standards and making them as centers for training graduate students in China. Material and financial aid from the United States will be used mostly for the rebuilding of these four or five selected institutions. It is hoped that arrangements can be made to bring visiting professors from American universities to teach in these selected centers in China. These centers, however, will not be able to turn out sufficient numbers of trained men to meet the needs of the nation. We must, therefore, look forward to sending a great number of students to be trained in the United States.

6. With reference to sending students to study in the United States, the following principles will be adopted:

(a) The laissez-faire policy will be abandoned.

(b) No students will be permitted to come to study in the United States unless they have fulfilled the requirements as to academic qualifications, practical experiences, and specific projects of study. This will be applied to all the students supported either by public or private funds.

(c) Only graduate students with practical experience in teaching, industry or government service will be sent to study in the United States. They should come with definite aims and projects and should know what they are expected to do when they return to China. They may not be required to follow the courses of study as prescribed for American students.

(d) A well qualified person is to be sent to the United States to act as the councilor for Chinese students studying in America.

This is the gist of the new program for reconstruction of higher education in China, upon the success of which not only the rebirth of China's culture, but also her economic reconstruction depend. The task will be tremendous. But we shall try to carry it out with firm resolution. However, in view of her exhausted conditions due to the war, China will not be able to accomplish this task without American assistance and cooperation.

DAVID DALE OWEN, MAN OF SCIENCE

By Dr. WALTER B. HENDRICKSON

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DAVID DALE OWEN, one of the leading geologists of the United States a hundred years ago, was one of the second generation of scientists who made New Harmony, Indiana, their home. Following the trail blazed by William Maclure, Thomas Say, Gerard Troost, and Charles Alexander Lesueur, the son of Robert Owen carried on scientific research in geology, chemistry, and paleontology.[1] At first he worked almost alone, but as he gained experience and enhanced his reputation, he gathered around him a circle of scientists who were leaders in their fields in the 1840's and 1850's. In the little town on the Wabash River, Owen built and maintained a large laboratory and museum which became the center of his operations as he worked on geological surveys for the United States government and for the states of Kentucky, Arkansas, and Indiana.[2]

What manner of man was this hard working, inquiring geologist? In the report of his most extensive and elaborate survey, that of Wisconsin, Iowa and Minnesota there is a portrait of the scientist.[3] It pictures an alert, rather handsome man with a high forehead, straight nose, sensitive mouth and strong chin. Owen's deep-set eyes were blue and his wavy hair brown. He was moderately tall, and though slight of frame, possessed a wiry strength and great stamina. Always immaculately dressed, he affected clothing in shades of gray. He was graceful in his movements, a skilled ice skater and an elegant ballroom dancer. A cultured gentleman, he was schooled in the social graces, and was reserved and quiet in public.[4]

David Dale Owen married Caroline Neef, a daughter of Joseph Neef, a former New Harmony school teacher, in 1837. When they returned from their wedding trip they moved into the "Owen Mansion" with Dale's brother Robert and the latter's wife. This arrangement continued for some years, but when the brothers' children became older, other plans were made. Dale sold his interest in the family home to Robert and contemplated the purchase of the house in which his sister, Jane Owen Fauntleroy, lived.[5] The sale was never consummated, but Dale and his family moved in with Jane and remained until Owen acquired a large dwelling near his laboratory.

This house, first built as a residence by Father George Rapp, leader of the religious group that originally founded the town of New Harmony, was later occupied by William Maclure and then passed to his brother and sister, Alexander and Anna Maclure, upon the death of their brother.[6] Erected as a two storied house, it had been converted into a one floor "cottage" with very high ceilings. It was a beautiful place with

[1] C. A. Browne, "Some Relations of the New Harmony Movement to the History of Science in America," in *The Scientific Monthly,* XLII (1936), 488–493.

[2] See Walter B. Hendrickson, David Dale Owen, Pioneer Geologist of the Middle West, Ph.D. Thesis (ms.) Harvard College Library.

[3] D. D. Owen, *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota* . . . (Philadelphia, 1852), 206.

[4] Caroline D. Snedeker, *The Town of the Fearless* (Garden City, 1931), 295, 302. Mrs. Snedeker is David Dale Owen's granddaughter.

[5] This house, known today as "The Old Fauntleroy Home," has been taken over by the New Harmony Memorial Commission, and is open to the public.

[6] This house, known today as the Rapp-Maclure-Owen House, is still occupied and is open to the public.

D. D. Owen.

spacious rooms and handsome fireplaces. There was a long and wide center hall with living and bedrooms on each side and a huge dining room at the end. Owen filled the house with books and pictures, some of the latter from his own brush. The hall was a museum with shelves along each side for the display of geological specimens. One of the most prized was a complete Ichthyosaurus from Germany which was an object of wonder to the Owen children.

The management of the household was left almost entirely to Mrs. Owen because her husband was either away from home engaged in field work, or if in New Harmony he was continually occupied in his laboratory. Caro, as Owen called his wife, managed the large house efficiently. In the garden plot and greenhouse nearby, vegetables and fruit were grown for the table. An ice house and smoke house were also part of the establishment. But Dale did take an interest in his home and occasionally bought things for it after consultation with his wife. At one time, though, he must have embarrassed her by sending home a whole bushel of hominy without asking if it was needed.[7]

Caro was somewhat in awe of her distinguished husband and had the mid-Victorian attitude that since he was the master of the house everything should be done to make him happy and comfortable. She admonished the children to be on their best behavior when he was present, and told them that their father was not to be disturbed nor inconvenienced under any circumstances. Yet Caro and Dale were very close to one another, each being completely in the other's confidence. Dale wrote Caro the details of his surveys and discussed matters of finance with her. His letters were cheerful and intimate and he exercised his great powers of description to make his life in the field real and vivid to her.

Four children were born to Caro and Dale: Alfred in 1841; Anna, 1843, William, 1847; and Nina, 1849. Owen loved his children and was always gentle and patient with them. Nina, the youngest, was permitted to go into the museum and laboratory and play about among the specimens and apparatus. Realizing the benefits he had derived from his own European education, Owen sent Alfred abroad in care of his sister, Jane, to attend school in Germany.

This quiet man had few interests outside of his home and his scientific work. He took no part in politics and his party affiliations are unknown. It may be presumed that he, like his brother, Robert Dale Owen, was a Democrat. Dale's appointments in the federal service were obtained in part through his brother's political connections. In fact, one of the main points made by Robert's opponent in the Congressional election of 1847 was that he "had got every brother and brother-in-law he had into *lucrative office*."[8] One other indication that Owen adhered to the party of Jefferson and Jackson was that he permitted enthusiastic supporters of Stephen A. Douglas to erect a campaign banner in front of his house in 1859.

The Hoosier geologist, however, held definite economic views to which he gave expression in many of his geological reports. He believed that the government should make resources available to the citizens; beyond this government had no further responsibilities. The best interests of all the people would be served by the utilization of the potential wealth in the ground, even though ore deposits were turned over to private individuals

[7] These and other details have been gathered from Owen's letters now in the possession of Mrs. Caroline D. Snedeker, and have been cited with her permission.

[8] R. D. Owen to Richard Owen, New Harmony, August 21, 1847, Richard Owen Papers. (Italics in the original.) These papers are in the possession of Mrs. Aline O. Neal, New Harmony, Indiana.

for exploitation. Owen was disturbed because Americans were not making full use of their mineral resources. He noted that the United States annually imported large quantities of lead although already possessed of huge reserves of ore in its own rocks. This practice, Owen said, prevented the nation from having a favorable balance of trade. Full utilization of lead and iron resources would stop the drain on the stock of gold bullion in the United States caused by the large importations.[9]

Although Owen in his later years wrote and spoke on nothing but scientific subjects, early in his career he made two public addresses in which he revealed some of his social and economic ideas. In 1844 he addressed the New Harmony Temperance Society. In his lecture the geologist emphasized the harmful physiological effects of alcohol. He said that if habitual drinkers were made aware of the damage that ardent spirits did to the body's organs they would cease their overindulgence. Owen based his cure for intemperance on the theory that "knowledge of the consequences of immorality is one of the strongest motives to morality."[10] The geologist approached the temperance question coldly and logically and advanced a solution drawn entirely from his own early medical studies and scientific training. He said nothing of the social implications of intemperance nor of the difficulties in the way of the regulation of man's personal habits and appetites. Owen failed to plumb the depths of this sociological problem, and merely expressed the theoretical views of the man of science.

Owen again drew upon his technical information in a Fourth of July oration that he delivered in New Harmony in 1845 in which he sought to explain the dangers which threatened the liberties of Americans. Although he admitted that political liberty had brought untold blessings to the people, he pointed out some of the "politico-economic paradoxes" which prevented the fullest realization of complete personal freedom. Particularly did he emphasize the fact that poverty and hunger existed in a land of plenty, that education was not available to the masses, and that, in spite of great mechanical advances, men still had to labor hard and long for small wages.

For the mitigation of these evils Owen had no concrete plan. He only said, "Necessity will come to our aid, . . . experience will guide us in the path: hope will cheer us on our way, confidence will ensure success." The "one bright star" was the law of progression which had been working throughout human history to bring political liberty to perfection. In earth history, too, the geologist found evidence of the operation of this same law of progress. Geology, "this searching—this penetrating science," he said, has proved that "race after race has passed away and become extinct, to be succeeded again and again by other forms belonging to higher orders in the scale of the animal kingdom." In the study of geology Owen discovered conclusive proof that "there has been, from the earliest periods, a continual accumulation and concentration of nervous and intellectual power—a tendency upwards, a striving after perfection—a law of apparently illimitable progression. . . ." Owen closed his address on a note of optimism and hope, saying, "With such evidence of the law of progress, and knowing the immense resources of science and art, what need, then of despondency? What more animating—more encouraging stimulus to labor in the cause of human perfection?"[11]

9 D. D. Owen, "Report of a Geological Exploration of Part of Iowa, Wisconsin, and Northern Illinois . . . ," *Executive Document* 26 Cong., 1 Sess., No. 239 (June 30, 1840), 39.

10 *Indiana Statesman* (New Harmony), April 6, 1844.

11 *Indiana Statesman*, July 12, 1845.

Certainly such sentiments were worthy of a son of Robert Owen. Cast upon a high moral plane, this speech indicated that at one time in his life David Dale Owen shared the optimism and idealism of his father and brothers. The ideas expressed were not original, except perhaps in the application of a scientific hypothesis to sociological theory. So far as is known, the geologist made no more public statements of his Utopian ideals. In his later life Owen was thoroughly absorbed in the practical details of geological surveying, and had little time to consider subjects which did not come directly within his own range of interest. In the field of science he was a profound and penetrating commentator; outside of it his ideas were trite and derived from the thoughts of other men.

In his chosen field the New Harmony scientist was an indefatigable worker. Not only did he accomplish a stupendous amount of field work, but when at home most of his time was spent in his laboratory. He was there early in the morning, came home for noon and evening meals, and, after a romp with the children, or a stroll for exercise, he returned to his office to labor far into the night.

Owen's headquarters buzzed with activity throughout the winter and spring when he was engaged on a survey. Many people of the town found employment there in outfitting the various expeditions. Wagons and carriages were overhauled, tents mended, general camp impedimenta renovated, and boxes made for specimens and cloth sacks made for soil samples.

For use in the field Owen designed a special wagon. It was a small, sturdy vehicle fitted with lockers for carrying instruments and supplies, and having a prairie schooner-like top. The geologist and his assistants often used a carriage for their own transportation while the sub-agents and laborers rode in the wagons. Owen took pride in having smart well-painted wagons and fine animals to pull them. One of his teams won a second prize for working mules at the Posey County fair.

It was in the 1850's that the renaissance of science in New Harmony under the leadership of David Dale Owen reached its height. During these years Owen was engaged on the survey of the states of Wisconsin, Iowa, and Minnesota Territory for the United States government; and he headed the Kentucky Geological Survey, directed the geological reconnaissance of Arkansas, and supervised the second geological survey of Indiana on which his brother, Richard, did the field work. Among the men whom Owen gathered about him were some future leaders of geological work in the Middle West, including Dr. Joseph G. Norwood, first state geologist of Illinois; Dr. A. Litton of the Missouri geological survey; and Dr. Edward T. Cox, a resident of New Harmony and the third state geologist of Indiana. Other leading scientists employed by Owen and who visited the town at intervals were Dr. Leo Lesquereux, the leading paleobotanist of the period, and Dr. William Elderhorst, a distinguished chemist and authority on blowpipe analysis.

In 1858 Richard Owen attempted to capitalize on the presence of these leaders and projected a technical school to be called the Indiana School of Practical Sciences. The laboratories and museum were to be used and Dale and his assistants were to be instructors. Dale was interested in the project because he realized that New Harmony had no commercial future, but felt that it might become an educational center. For some unknown reason the school failed to materialize, and Dale Owen was much too busy with his own work to give attention to the matter. It must have been at least a momentary disappointment to him, though, because he had hoped to enlarge the circle of scientists in New

Harmony, and he had invited Dr. Robert Peter, the chemist employed by Owen on the Kentucky survey, to bring his family and become an instructor in the school.[12]

Although Owen's relations with other men were usually pleasant, he was somewhat impatient with dull wits. Generally soft-spoken, he wielded a caustic pen when aroused by incompetence or failure to understand scientific matters. In 1845 he had appeared in St. Louis to give a series of lectures on chemistry and geology. The audiences were quite small and he barely made his expenses. He wrote to his wife bitterly denouncing the citizens as "ignorant, selfish, moneymaking people with no taste for science." On another occasion he soundly berated an engraver who misinterpreted one of his geological sketches. Yet Owen inspired loyalty and affection in other men. A Dr. Bell of Louisville wrote to a Congressman, " 'Permit me to introduce to your acquaintance Dr. Owen; if you can avoid loving him then I shall consider the age of miracles has come.' "[13] Owen's topographical assistant on the Kentucky survey, Sidney S. Lyon, stoutly defended his chief against attacks by some members of the legislature who wanted to displace him as head of the survey.[14]

The Hoosier geologist was ambitious and he was criticized by jealous rivals. When Owen was seeking the appointment as state geologist of Kentucky, his old assistant in the Northwest, Joseph G. Norwood, who would have liked the place for himself, accused Owen of ruthless acquisition of specimens. Norwood said that Owen personally appropriated all specimens collected on public surveys.[15] Owen, like all confirmed collectors, did use every means to enlarge his museum and his various official positions gave him unexcelled opportunities for adding to it. Norwood's charge, however, was not entirely justified because Owen always obeyed the letter of his instructions and supplied collections whenever they were called for. One can not refrain from believing, though, that the best of the specimens found their way into the New Harmony museum.

David Dale Owen was, as Dr. Peter said, "Unselfish and ever careful to give everyone his due, [and] he always awarded to his various associates . . . their just share of honor and responsibility."[16] Dr. Peter was himself a beneficiary of Owen's generosity. The chemist made so many soil analyses in such a short time that he was accused of falsifying his data. Owen rose to his defense, and in the fourth report of the Kentucky survey gave a careful explanation of the time-saving methods used by Dr. Peter and paid high tribute to his ability as a scientist.

Thus one sees Owen the man and Owen the scientist as one and inseparable, for Owen the man lived only to be Owen the scientist. His relations with his family and with fellow citizens were inextricably bound up with his intense and all-absorbing interest in science. On the other hand he was the same quiet and sympathetic but zealous and particular man in his professional relationships that he was in his home and community. The portrait appears almost naively simple, delineating an honest man with a single purposeful interest.

[12] D. D. Owen to R. Peter, New Harmony, October 30, 1858, Peter Letters. Permission to cite these letters was given to the author by Dr. Alfred Peter, the son of Dr. Robert Peter. They are now the property of Translyvania University.

[13] D. D. Owen to Mrs. D. D. Owen, St. Louis, March 12, 1845, D. D. Owen Papers; D. D. Owen to J. H. McChesney, New Harmony, March 8, 1859, in Indiana State Library; D. D. Owen to Mrs. D. D. Owen, Washington, D. C., February 3, 1853, D. D. Owen Papers.

[14] Sidney S. Lyon to R. Peter, January 2, February 27, March 25, 1858, Peter Letters.

[15] J. G. Norwood to R. Peter, New Harmony, July 3, 1854, Peter Letters.

[16] R. Peter, "Obituary Notice of David Dale Owen," in D. D. Owen, *Fourth Report of the Geological Survey of Kentucky* . . . (Frankfort, 1861), 329.

METEORITES AND THE MOON

By Dr. H. H. NININGER

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THE face of the moon has been the subject of many and varied discussions attempting to offer a satisfactory interpretation of its peculiar features. Nearly all the writers of these articles seem to have assumed that vulcanism on the moon has been established and that the burden of proof that it is not true rests upon those who offer alternative or supplementary hypotheses as explanations of the lunar features. Clearly, any true volcanic activity that may have existed on the moon was so ancient that the resulting topographical features have long since been erased by meteoritic bombardment of its surface. Meteoritic bombardment is an undeniable fact which has been studied on the earth and is known as a cosmic process to which the moon is necessarily subject. It will be shown that this process is sufficient to account for the principal features of lunar topography.

Before presenting evidence supporting the meteoritic hypothesis of the origin of lunar features, a few of the more conclusive objections to the volcanic theory will be presented. In the first place, the moon is without water and a sensible atmosphere. On the earth, vulcanism is limited almost entirely to sea bottoms and to land bordering the oceans. The process appears to be related to sedimentation and possibly to removal of material by air and water from one place on the earth's surface to another.

On the earth a volcanic crater is usually a secondary feature of a volcanic cone which has been built up by the extrusion of lava. If the crater exists, its floor is generally far above the surrounding landscape. Now, if vulcanism existed on the moon, the resulting cones and their crater floors should be even higher than those on the earth because gravity on the moon is only one-sixth of gravity on the earth. Although relatively low gravity favors the wide scattering of materials on the moon, it in no way interferes with the welling up of more lava to replace that which may have been ejected and scattered.

Thermal and photometric studies of the moon indicate the presence of a blanket of porous material. This fact is consistent with either the volcanic or the bombardment hypothesis.

Careful scrutiny of lunar photographs[1] reveals lunar pits representing activity which dates back a long time and has continued to a very recent geological age. In that portion of the satellite where the pits are more abundant we see superimposed, one upon another, a long succession of forms consisting of some which are so ancient that their battered and buried remains are barely discernible and upon which rest others representing all stages of deformation, even some which appear so fresh that they may have been formed since the Pleistocene age on the earth. The defenders of the volcanic hypothesis have always been faced with the fact that any vulcanism must be dated far back in lunar history. Some attribute its features to the collapsing or explosion of gas bubbles formed on a plastic surface. Evidently no explanation of lunar craters can be satisfactory which does not allow for the

[1] For photographs the reader is referred to the article, "The Surface Features of the Moon" by Dr. Fred E. Wright, THE SCIENTIFIC MONTHLY, Feb., 1935.

process of their formation to continue until recent times.

The unequal distribution of the lunar pits over the surface of the moon has been urged as evidence against the bombardment hypothesis. As a matter of fact, their wide and abundant distribution constitutes a far more serious objection to the volcanic hypothesis than does their unequal distribution against their meteoritic origin.

Except for portions of the *maria* and some of the mountains, no small bit of the lunar landscape has escaped being, at one time or another, a portion of the rimmed pits. And on much of the surface the pits overlap or are contained one or more within another. There is no evidence there has ever been such widespread vulcanism on our planet, where conditions are and have been favorable to it. Far more of the earth's surface is free from lava and volcanic craters than is covered by them. Besides, if vulcanism is to explain the lunar pits, then the *maria* represent enormous lava flows, not only more extensive than any known on the earth, but of such magnitude as to have inundated innumerable rimmed pits of all sizes, traces of which may easily be detected on the best photographs. Judging by the present height of the rims of similar pits outside the *maria*, we must assume that many of these rims rose thousands of feet above the general surface level. Yet, at the present time, the *maria* lie thousands of feet below the average level in adjoining portions of the moon's face. Such an extensive lava flow would, on the earth, require an origin some miles above the periphery. On the moon, because of its smaller surface gravity, it would need to be much higher. Yet measurements reveal no central elevation whatever.

The Battle-Scarred Moon

In presenting the meteoritic or bombardment hypothesis, we deal with a cosmic process within whose domain the moon, no less than the earth, resides. In presuming to treat of this process we are reaching no farther beyond our experience than does the astronomer when he assumes gravity on the moon or the effects of solar heat on its surface. Vulcanism, on the other hand, is strictly a terrestrial process as far as we know, and any attempt to project its activity beyond the confines of our planet must rest upon a clear and unmistakable demonstration that the conditions under which it operates obtain there.

Meteorites are known to bombard the earth at the rate of about one million per hour, of sufficient size to render their courses through the atmosphere visible to the unaided eye. How large these bodies must be in order that their accompanying luminous phenomena (meteors) shall be visible at a distance of 100 miles (the average distance at which we observe ordinary naked-eye meteors) is a matter not yet agreed upon. Formerly, they were considered comparable in size to grains of sand, but recently they have been compared in size to marbles by those astronomers who have given them closest study. It is generally agreed that telescopic meteors are thousands of times more abundant than naked-eye meteors. Dr. C. C. Wylie has recently stated that their number "on the earth per day probably runs into millions of millions."[2]

Of the naked-eye meteors, there is a considerable number of such magnitude that they can be seen in daylight. At night these appear as extremely brilliant fireballs and often detonations are heard by those within twenty to thiry miles of their point of disappearance. Observations through a period of seventeen years have led the writer to believe that from seventy-five to one hundred such falls occur per year within the borders of the United States. Dr. Wylie, who has made

[2] *Popular Astronomy*, 44: 91–2, 1936; University Iowa Obs. Contr. No. 7, 226–7, 1937.

observations in the north-central portion of the United States during almost the same period, has arrived at about the same conclusion. He places the number at ninety per year for the United States and assumes an average weight of ten pounds for them. He worked out a probability curve for meteorites of various sizes encountered by the earth. The following figures are taken from the paper previously referred to (the second item in each statement is mine):

Meteorites of weight ten pounds or more, about ninety per year in the United States. Entire earth, 5,280 per year.

Meteorites of seven thousand pounds or more, two every three years in the United States. Entire earth, forty-three per year.

Meteorites of fifty tons or more, one every thirty years for the land surface of the earth. Entire earth, one in ten years.

Meteorites of two hundred and twenty tons or more, one in one hundred and fifty years for the land surface of the earth. Entire earth, one in fifty years.

Meteorites of fifty thousand tons or more, one in 100,000 years for the land surface of the earth. Entire earth, one in 33,000 years.

It should be noted that the estimates of the naked-eye meteors and of the first item in the foregoing list are based on actual counts. The weights are theoretical, as are all of the items listed, but they agree fairly well with observational data. In cases where there are discrepancies, the observational data indicate that Wylie's estimates are too low rather than too high.

While all the meteorites producing ordinary meteors or "shooting stars" (one million per hour) are destroyed by our atmosphere, each and everyone of this size would actually blast the moon's surface. This fact means that one impact occurs for each square mile approximately every 40 days; or one per square yard every 35,000 years. The surface of the moon would be bombarded by meteorites at an approximately equal rate.

The average velocity of these "marble-sized" missiles is about 26.2 miles per second. No one knows exactly what would be the effect of such an impact, but we do know that a 46-grain metal projectile fired at a speed of 4,250 feet per second (muzzle velocity) against a piece of steel armor plate, explodes with such violence that it blasts a hole in steel plate about one and one-half inches across and one-fourth of an inch deep. The same size projectile fired with a muzzle velocity of between 7,000 and 8,000 feet per second blasts a hole in steel armor two inches deep and two and one-half inches across. It should blast a much larger hole in brittle rock structure. The marble-sized meteorites of the stony variety will compare favorably in mass to a 46-grain projectile. We do not know, however, just what is the ratio between the blasting effects of a projectile traveling at the bullet speeds described and those of meteorites. Applying the rule that the energy of explosion increases as the square of the velocity, we find that the meteorite whose velocity is more than 16 times as great as the highest-speed bullet referred to would be more than 200 times as powerful as explosive as is the bullet. Unquestionably, it would blast a hole in solid rock several feet in depth. Similar impacts are taking place on the surface of the moon; every square yard of its surface receives one of these missiles every 35,000 years, on the average, and nearly 3,000 times in 100,000,000 years, or in relatively modern geological times.

Meanwhile, about 60,000 (estimated) meteorites averaging ten pounds each have landed on each square mile, traveling at similar velocities. Imagine the holes blasted by those invaders whose

weights average more than 2,000 times those of the small ones previously mentioned!

During the same 100,000,000-year period there have been about 500 (estimated) meteorites averaging 7,000 pounds each on every square mile; and on each square mile a mass of 50 tons has arrived to blast a gigantic crater. During the same period, the entire surface of the moon has received about 142,000 meteorites (estimated), averaging 220 tons each and 71 (estimated) averaging 50,000 tons each.

The Lunite Mantle

In view of the blasting action of high-speed bullets and their comparison with even the smallest meteorites, it is evident that the mantle of finely-divided lunite cannot be thought of as being only a few centimeters in depth. The bombardment by meteorites of ten pounds in weight would pulverize the surface to a depth of many feet in comparatively short time, to say nothing of larger impacts. The explosion in and under the mantle would throw that material high, far and wide, because there would be no air resistance and but low gravity to interfere. Much of it would fall back into the pit and be melted along with portions of the sub-mantle to form the level floor which is such a prominent feature of these pits and which led some writers to refer to them as "ringed plains." Many of the pits are marked by cones rising from the centers of their floors. These cones may have resulted from secondary volcanic action which for a time continued as a result of the intense heat generated at the point of contact with the solid sub-mantle. The rimmed pits are very variable in form as well as in size. Some have no level floor and have massive, buttressed walls. Others have expansive level floors and narrow, less elevated rims. The central cones are more prevalent in the former variety. These differences may be due to the types and differences in size of meteorites involved or to the velocities at which they were traveling. A nickle-iron meteorite might pass through the cindery mantle and to some extent penetrate the solid sub-mantle before exploding, which would tend to interfere with the lateral scattering and result in a higher and more massive wall. On the other hand, a very large stony meteorite would explode without any penetration of the sub-mantle and produce a very wide, shallow pit. Its large mass and subsequent heat would fuse all of the material which fell back into the pit and encroached upon the wall, producing a sizeable but shallow lake of lava. As a result of the melting a very great subsidence takes place so that the surface of the fusion pool will be greatly lowered, the amount depending upon the size of the particles and the depth of the material involved. This fact makes very clear the reason why the lunar pits have floors which are lower than the surrounding plain. All of the efforts to explain this depressed interior of the pits in terms of vulcanism have proved to be entirely unsatisfactory; yet this is about their most distinctive feature.

When a large metallic meteorite penetrates the lunite mantle and explodes, it produces a deep pit in the sub-mantle. There are several reasons why a free-flowing volcanic action may be assumed to follow in the central part of the floor of such a pit: Here is the point of greatest heat concentration due to impact; the pool of melt is here several hundred or perhaps thousands of feet deeper than in other parts of the floor and consequently will be slow in cooling; chemical action between meteoritic material and adjacent rocks is likely to develop, giving rise to ebullition; when other parts of the lake have frozen over the central area will continue to boil; as this central area begins to freeze over ebullition will con-

tinue from below and the viscid lava will be spewed out and will build for itself a cone, which compared with those on the earth, will rise, because of the low gravity on the moon, to much greater heights and in much steeper cliffs. The craters, *Archimedes, Autolycus* and *Plato* are examples of those with narrower rims and flat, coneless floors, while *Copernicus, Eratosthenes* and *Aristillus* have more massive buttressed walls, bowl-like floors, and central cones. In certain of the pits there appear, instead of cones, small central craters which seem to be of about the same age as the rims inclosing them. This condition may have been due to a much less protracted volcanic action, more on the order of that which sometimes produces an explosion crater on the earth where a lava flow covers an active vent, temporarily sealing it in, and where finally sufficient pressure is generated to cause it to explode. The same thing might happen under the fusion floor of a lunar pit where the conditions in the depths of the explosion cup were such that its heat was sufficient to cause one good explosion but produced no lava flow thereafter. These secondary explosion craters should be distinguished from impact craters of the ordinary type seen within the larger pits and which postdate the floor upon which they are superimposed. These may appear in any part of the floor or rim of the larger primary crater. *Clavius*, for example, shows four fresh-looking, good-sized craters besides numerous small ones upon its floor and several upon its rim. All these are plainly more recent, however, than is *Clavius* itself. Many other similar instances could be cited.

This brings us to the consideration of the *rays* which so conspicuously reveal themselves at the time of the full moon, when they are seen extending outward hundreds of miles from certain of the pits. They have been shown to have no considerable elevation. They seem to pass uninterruptedly over hills and valleys, pits and rims, alike, some of them extending as far from their point of origin as 1,500 miles! They must either represent mineralogical peculiarities which reach deep into the satellite's interior or must have been laid down in recent geologic time. Otherwise they would have been destroyed by meteoritic bombardment.

Dr. L. J. Spencer has lately suggested an explanation of the rays which seems to deserve serious consideration.[3] He proposes that, when large metallic meteorites exploded, the metallic vapors condensed into minute spherules such as he has found embedded in the fused silica collected around the Wabar, Arabia, and Henbury, Australia, craters. These spherules, because there was no air resistance and very slight gravitational restraint, were shot out to great distances. There being no atmosphere, the bright metallic globules have remained bright and thus give the whitish effect of diffused light. He has called attention to the fact that "the ratio of the number of craters showing bright rays and spots to those without these features is of the same order as the ratio of the numbers of irons and stones that reach the earth." I wish to call attention also to the fact that those "craters" which give rise to the now-visible rays are all fresh-looking craters, indicating comparatively recent formation, while others of the same general form, but older, show no rays. Naturally, the rays may have been there but have been obliterated. We may note also that the rayed craters are all of the deeper, buttressed-wall type, as we have earlier pointed out and were probably produced by the metallic meteorites which penetrated to great depths.

We come now to the consideration of the *maria*, those relatively smooth areas called "seas" by Galileo who first looked at the moon through a telescope. Here

[3] *Nature*, 139: 655–657, 1837.

have occurred the most phenomenal of all happenings in the history of our satellite. Great areas of lunite as large as the states of Kansas, Nebraska, and Colorado combined were melted down, according to the meteoritic theory, by the collisions of cometary swarms of meteorites. Approximately half of the face of the moon which we see from the earth has undergone this kind of ordeal. It is surprising that Professor Shaler, who rejected the impact hypothesis as applied to ordinary lunar "craters," accepted this explanation of the *maria*. Our explanation differs from his only in certain particulars.[4] Whereas he chooses to account for the phenomena on the basis of an encounter with one body, of planetoidal proportions, in the case of each of the *maria*, I am strongly inclined to consider each *mare* as the result of a collision with a cometary swarm of smaller masses; and whereas he considers it more probable that all of the *maria* were produced at the same time, I am very well convinced that they represent differences in age. Had such a *mare* been produced by the impact of a single body, the mass would surely have penetrated to such depth that we should find evidence of subsequent vulcanism. Huge lava cones certainly would have grown up in the centers of the fused areas and probably at many other points on their surfaces. Such phenomena are notably absent. At first, I sought to ascertain whether *Copernicus* and *Kepler* might represent this kind of process on the plain of *Oceanus Procellarum*. Not only do they fail to show the great elevation above the plain which this interpretation demands, but the ray system of *Copernicus* clearly spreads over much of the surface of *Mare Imbrium*, which is evidently of considerably more recent origin than *Oceanus Procellarum*.

[4] N. S. Shaler, "A Comparison of the Features of the Moon and Earth," Smithsonian Contr. to Knowledge, pp. 1–130, 1904.

Comets are rather abundant in the solar system. It has been fairly well established that their nuclei consist of swarms of meteorites. How large are the bodies that compose these swarms is not known, but we may assume that those of planetoidal dimensions are rare. Let us suppose that a swarm of meteorites a few hundred miles in diameter is composed of various-sized masses up to fifty or one hundred million tons, the total weight of the swarm running into billions of tons. Collision with such a swarm would involve no deeper penetration than would the impacts of solitary masses such as formed the larger "craters," but the fusional action of the various units would coalesce into one great lake.

Cometary encounters, such as may possibly have caused the *maria*, may well be considered as having been responsible on the earth for the puzzling succession of *geological revolutions* which mark the principal time divisions in historic geology.

In our discussion we assume an atmosphereless moon. We are aware that some students believe that the moon has a tenuous atmosphere comparable to that which exists at elevations of forty to fifty miles above the earth's surface. There seems to be a fair way to settle this question. The majority of our naked-eye meteors are at such heights and greater. This fact means that if such an atmosphere were present on the moon, comparable to that surrounding the earth, invading particles would encounter the same resistance as they do at similar elevations above the earth. Therefore meteors should be as bright and numerous as they are here in our atmosphere. We view our meteors from an average distance of about 100 miles. This is well above the observational optical distance at which the moon is ordinarily studied through the largest modern telescopes. Then, surely, the

dark portion of the moon's disk should be an excellent field for observing meteors, if there is a lunar atmosphere. Naked-eye meteors are blazing through our atmosphere at the rate of a million per hour; hence the moon should have a rain of about 70,000 per hour. These should surely present a beautiful display for the telescopic observer, far better in fact, than do ours here in our own atmosphere because we are better situated for seeing a large area at one time. Haziness due to angular penetration of our atmosphere does not bother at all in our vision of the moon. We can choose a time which allows vertical penetration of our own, and if the moon has an atmosphere, we are viewing it from the outside. Consequently, if any meteorites are being consumed there, we should be able to see the resulting light more clearly than we do any but the brighter of terrestrial meteors!

On the other hand, striking the mantle of lunite as their first resistant medium, even though they doubtless do give forth a flash, it could appear as only an instantaneous spark to the observer at the telescope, because they are immediately buried under opaque lunite. Even at the instant of the flash, only large meteorites would produce flashes bright enough to be visible from the earth. Falls might be detected if one were fortunate enough to be looking at the moon at the right moment, but it is probable that craters of a mile or more in diameter have been formed not oftener on the average than once in a thousand years on the entire moon.

In view of the shielding effects of our planet and the absence of any atmosphere pyrotechnically to herald the arrival of meteorites on the moon before they actually plunge into the lunite, we may not look forward with much expectation to witnessing any change on the surface of our satellite. However, it is not impossible that we may do so, and every effort should be made in the direction of the most painstaking scrutiny and the most careful comparison of lunar photographs taken at different dates. The earth acts as a shield against all meteorites whose courses lead them to pass within somewhat more than 200,000 miles of this planet, so that in our time while the moon exhibits no rotation relative to the earth, the majority of its encounters with meteorites are entirely out of our range of vision.

Other Lunar Features

Without attempting to deal with all problems of lunar topography, there are yet some which should be considered. A few (less than one per cent.) of the "craters" have floors which lie above the level of the plain outside their rims and one, a rather large one, in particular exhibits no rim at all but appears as a plateau with steep sides and level summit, as if an ordinary, large, rimmed pit had been filled to the brim with molten material and then cooled in place. This, indeed, is what probably happened. Let us assume that a *mare* plain had been formed and had not yet thoroughly cooled. Its surface had frozen over to a considerable depth, but a large body of molten lunite was sealed within it. At such a stage the *mare* would be in a shrinking condition. Into this frozen-over lake of lava a large meteorite fell. The crust was penetrated, the usual rim was thrown up, but instead of the pit remaining empty it was filled by the welling up of viscid lava due to the pressure of the subsiding plain. Such features are scarce for the reason that large meteorites have fallen so infrequently that they have seldom arrived when exactly the proper conditions existed to produce them.

Much more common features are the small mounds on otherwise level surfaces of the *maria*. These may be a mile

or more in height and twice as wide. They have been termed *laccoliths* by some writers, but a true *laccolith* would presuppose that the conditions requisite for vulcanism existed at the time of its formation. Since the time when true vulcanism may be reasonably assumed to have existed, the meteoritic bombardment must have obliterated all such features. They may very well have been formed by meteorites perforating the crust of a lava lake at an earlier stage when its crust was not so thick and when the lava was more fluid, with the result that a small mound was formed by extrusion, concealing any rim that may have been produced by the meteorite's penetration.

Other mounds show funnel-like openings in their summits as though a bubble in viscid matter had started to collapse. Still others seem to have fully collapsed. These are what might be expected where foreign materials are being intruded, from without, into the lunite. Meteorites carry considerable amounts of chemcially active ingredients. Naturally there will be developed certain chemical activity accompanying the heat of impact. Ebullition will result. Some of the gasses escape, but in some cases pockets or bubbles will form and these may become frozen at any stage on their way to escape at the surface.

The rills and deep gorges which are quite numerous on the moon present something of a problem. Many of the straight, furrow-like structures may be the result of meteoritic encounters in an almost horizontal plane. Others are probably the results of faulting which must of necessity have accompanied the gigantic collisions represented by the larger pits and the *maria*. They must have been produced contemporaneously with the production of other conspicuous lunar features. Otherwise they could not have survived.

WHAT IS KNOWLEDGE?

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COMMON sense tells us that the table in our room is colored and solid, has size and shape, is heavy and endures. It exists where it is without depending upon us for its existence. If we left the room and came back later, it would still be there and would have been there all the time, unless, of course, somebody or something had moved it. Our looking at it does not affect it, does not change its nature, does not modify it in the least. Its color, size and shape are really just as we see them. We could feel its weight if we lifted it. Many of us can look at it and all see the same thing. These statements may seem so obvious that it is foolish even to mention them. If one claims they are untrue, he may be considered mentally unsound. Yet, common sense itself leads us to question them and eventually to deny many of them.

NAIVE REALISM

In order to identify the views more or less commonly held by unreflective people, epistemologists have coined the term "naive realism." The naive realist is a "straw man" set up to represent us in our unreflective moments. This straw man is not quite like any of us, for most of us have reflected somewhat. Thus naive realism must be, paradoxically, a reflective statement of an unreflective view. It may be summarized as follows:

(1) Objects are independent of their being known. They can endure or continue to exist without being experienced by any one.

(2) Objects have qualities (properties, characteristics, attributes) which are parts of the objects.

(3) Objects, including their qualities, are not affected merely by their being known. They are neither made nor changed merely by our knowing them.

(4) Objects seem as they are and are as they seem. Appearances are realities.

(5) Objects are known directly, *i.e.*, they are in experience. There is nothing between them and our knowledge of them.

(6) Objects are public, *i.e.*, they can be known by more than one person. Two or more people can see the same object.

Criticisms of Naive Realism

Trouble arises for the naive realist when attention is called to the fact that statements 1 and 5 are incompatible. Objects are independent of experience and yet are in experience. One's experience, knowledge, ideas, are located within one's head. But objects are located outside of one's head. How can objects which are outside of one's head be in experience which is inside of one's head? Trouble arises for the naive realist also when he faces the fact of error. When errors are called to attention, we recognize them and are happy that we have now arrived at the truth. But if asked what assurance there is that the new view is true, we reply that it seems true. But this is the same assurance that we had of the error before it seemed to be an error. Trouble arises for the naive realist in modern times because so much reflection by others has taken place. He is constantly confronted with evidence that the qualities which objects have are conditioned by various factors affecting different people differently and the same person differently at different times. In a world of science, the naive realist has a hard time retaining his naiveté.

Criticisms of naive realism may be classified for convenience under four headings.

(1) *It fails to account satisfactorily for error.* If things are as they seem and seem as they are, then whatever seems to be so is so. Such a view makes error theoretically impossible, for an error is something which seems to be so but isn't so. Recall the common experience of seeing a stick partially submerged in water. Upon first sight the stick appears bent or broken. If naive realism is taken at its face value, then if the stick seems bent it is bent. If the stick is pulled out of the water, it is seen to be straight. Does the stick bend as it goes into the water? Previous experience with sticks and water usually suggests "No." But the stick appears to bend as it goes into the water. What, then, can be done to determine whether the stick is really bent or really straight? For the moment it seems both bent and straight. Since it can not be both, one of the two appearances must be erroneous. The next step commonly taken is to run one's hand along the stick down into the water. To the hand the stick seems straight, even though to the eye it seems bent. The stick is really straight. He dismisses the bent appearance as an error or illusion, and drops the matter. But what are illusions? They are objects which are not as they seem. If some objects are not as they seem, then it is false that all objects are as they seem. If some objects are not as they seem, what makes seeming sometimes "so" and sometimes "not so," and how often is seeming "so" and how often "not so"?

Examples of error trouble the naive realist, but they trouble him little. He goes from conviction to new conviction, confident in the reliability of his newest view. When pressed with the query,

"But how can you tell that your new conviction is more reliable than the one given up as erroneous?" he often answers, "Well, I just know." Or, if you get him in a corner and prod him for an explanation, five kinds of replies eventually come out: (a) He appeals to his other senses for corroboration. (b) He compares with past experiences. (c) He repeats the experiment. (d) He invokes the testimony of others. (e) He appeals to instruments.

(a) If appearances derived through one sensory channel appear contradictory, it is natural to appeal to other senses for corroboration. If a dull ring indicates that the china is cracked, one naturally feels with his finger and looks to see. But sometimes different senses contradict each other and sometimes different senses corroborate in error. When senses contradict each other, which shall be accepted as reliable? The half-submerged stick looks as if bent, but feels straight. The distant carpenter's hammer stroke is seen to stop but heard to continue. When senses corroborate in error, one is still more baffled. Who has not had the experience, in a railway terminal, of having the train start moving? First he feels the rumble of the wheels over the tracks, and hears the movement of the wheels under him, and looks out to check to see if he is at last moving. Then he is shocked to find that not his but the next train is moving.

(b) Comparison of present paradoxes with past experiences involves greater possibilities of error and greater paradoxes. For past experiences, to be compared, must be remembered. But memory often has failed us. How can we be sure that it is not failing us again? And the past experiences themselves might have been erroneous. Can the possibility of erroneous recollection, added to the possibility of erroneous past experience, be used to deny evidence present at hand? Perhaps, however, recollection of experiences repeated in the past many times may be considered more reliable than a single present experience. Yet experiences in the past may have been consistently erroneous.

(c) Doubts sometimes lead to experimentation. Is the bent stick really straight? The naive realist pulls it out and puts it back in several times and feels of it several times to prove that it is really straight. But how can he discount the fact that it also appears bent repeatedly? Also, if past experiences can have been consistently in error, why not present and future experiences?

(d) When doubts about one's beliefs become serious, it is natural to consult others. "Does this stick look bent to you? Feel of it and see if it isn't straight." Gregarious naive realists derive much satisfaction from social corroboration, but they fail to recognize two things. First, their perception of other people as objects which may be consulted is also liable to error. Most of us have mistaken manikins, mirror images and movie motions for real men. Or in dreams we have consulted our friends and gained their agreement. What test is there that there are real people to consult? Secondly, even if we consult real people, are they not subject to the same errors as we? Can not people be in agreement and yet be in error? For centuries people agreed that the earth was flat. If others share our error, what can we profit by consulting them for proof?

(e) The last resort of the naive realist is an appeal to instruments. Heat is measured by thermometers. Weight of purchases is measured on scales. The color of blood is revealed under a microscope. But the appeal to instruments, like the other appeals, is a confession of failure. For it is a confession that apparently obvious objects are not self-evident. And an appeal to instruments is an appeal to reflection. To the extent

that men are reflective they cease to be naive.

Before we let the naive realist out of his corner, let us ask him one more question: "How can you tell that you are not dreaming?" He naturally replies, "I can pinch myself to see if I am awake." "But can you not dream of pinching yourself and convincing yourself that you are awake?" "Yes, but I can ask others if I am awake, and can walk and run and read." "But can you not dream of doing these also?" He is forced to admit, "Yes," but persists in discovering additional suggestions, including that of waking up. But people sometimes dream of waking up and dream of waking up their friends to cooperatively settle their dreaming doubts. If there is nothing in one's waking moments about which one can not dream, and if dreams seem real, then what assurance has one that he is not now dreaming? If he has none, then in how far is he justified in maintaining the truth of his beliefs any more than a dreamer has? How can he tell when he is in error?

(2) *It fails to take into account the extra-organic and intra-organic conditions of knowing.* Some scientists describe the human body as an organism and distinguish for convenience between extra-organic and intra-organic factors, *i.e.*, factors outside the body and factors inside the body. If many factors between the thing causing the idea and the idea itself affect the idea, then the idea may be different from what it would be if it were influenced by the thing alone. Let us consider a few such factors.

Extra-organic conditions of visual perception include light sources, pigments, atmospheric conditions, glasses. Light sources are of many sorts, and what one sees may be stimulated by a single source or many sources, by light of a single frequency or of mixed frequencies, by light of a single intensity or of many intensities, shining from one angle or from many angles. All these make a difference. Some pigments absorb all rays, others none, others some. Atmospheric conditions affect visibility, exemplified by fog, snow, dust, rain and heat waves. Glasses, telescopes, microscopes, their accuracy, their adjustment, their color, all affect perception. Does the real nature of things change as these intervene? Furthermore, the distance which light waves travel is a factor which naive realists neglect. If light travels at a rate of 186,000 miles per second, some fraction of a second is required for transmission from table to eye. So we "see" the table, not as it is when the light wave reaches the eye, but as it was when the light wave left the table. Such fraction of a second seems so insignificant in the total reaction involved in perception that it may be ignored for practical purposes. When distances become great, however, the significance changes. Astronomers astound naive realists with assertions that stars which seem to be up there have long since ceased to be there.

Visual perception is conditioned intra-organically by the complicated nature of eyes. Before a colored table can be perceived, light waves reflected from the table's surface must travel through some medium to the surface of the eye, penetrate the skin, travel through the aqueous humor, the lens, the vitreous humor, to the retina and its rods, which react to variations in light intensities, and its cones, which react to variations in wave frequencies. These cells behave like little chemical batteries or photoelectric cells. When stimulated by light they generate electric currents or nervous impulses which are sent through neurones to the brain. Somehow the brain functions in such a way as to produce attention to, and consciousness of, the object being experienced.

How can color, which the naive realist supposed the table to have, travel on light waves which are merely high-frequency

vibrations, penetrate skin, liquid and lens, then undergo chemical transformation, travel through neurones as electrical impulses, enter conscious experience unchanged?

How can shape, which the naive realist supposes the table to have, be transmitted into conscious experience? Rays traveling simultaneously reach different parts of the curved cornea at slightly different times, travel through a mobile doubly-concaved lens, reach the curved rear inner surface of the eyeball only after being inverted. Then the rays stimulate chemical reactions in the rods and cones; but these may react at slightly different rates, if they are variously fatigued, or some may not react at all. What happens to the supposed shape of the table during these chemical reactions? Then nervous impulses are set up traveling through the optic neurones of different lengths, which twist maze-like on their way to and in the brain. Since we see with two eyes, we really get two sets of patterns of rays. Impulses through the optic nerve split in such a way that those coming from the right half of each eye terminate in the left rear lobe of the brain and those from the left half of each eye in the right lobe of the brain. These lobes seem to be separated from each other by a longitudinal fissure. How can the supposed shape of the table stand such distortion, transformation, duplication and separation without affecting its appearance?

How can size, which the naive realist supposes the table to have, be transmitted into conscious experience? The table-top is three by five feet. But that size can not really be contained within a head wearing a size seven hat. Size too must be transmitted through a tiny hole called the pupil and meander through twisting brain-paths. Not size but, at best, relative size can be perceived.

(3) *It fails to take into account differences in public knowing.* To the previously mentioned extra-organic and intra-organic conditions we may add some which emphasize differences between people. Naive realists believe that two or more persons can see an object at the same time and all see it as it is. Thus all these people can have exactly the same experience. But disputes about objects illustrate differences in experiences. Also, scientific tests have been devised to demonstrate these differences, as for example through colorblind tests and the anomaloscope. The anomaloscope is a system of prisms and lenses mounted in a tube such that one can see through an eyepiece two halves of a lighted circular field, the color and intensity of which are controlled by screw-adjusted slits permitting monochromatic yellow light (589 millimicrons) to reflect from one half and a mixture of monochromatic green light (536 mm) and monochromatic red light (670 mm) in any proportion to reflect from the other half. Tests show that when one person has adjusted the anomaloscope so that both halves of the visual field appear equal in color and intensity, another person who looks will object that they appear different and will require readjustment to make the halves appear equal. Thus is demonstrated reported differences in experience when extra-organic conditions of stimulation remain constant. Thus obviously different people may not see the same object as it is, but experience different objects when confronted by the same stimulus source.

(4) *It fails to take into account the "constructed character" of knowing.* The term "constructed character"[1] of knowing may be used to name the synthesizing process that goes on in the brain before experiences are produced. The various nervous impulses do not appear in consciousness to be consciously assembled or constructed into an object. Objects appear in consciousness as

[1] Roy Wood Sellars, "Principles and Problems of Philosophy," p. 52.

wholes. They enter experience already made. Some unconscious or subconscious process determines our conscious experiences for us, even though we can never become aware of it. The mystery of consciousness may never be explained satisfactorily, but it is obvious to those who reflect that something happens within us to make us see things the way we do. This something must be taken into account in explaining the nature of knowledge.

Perhaps the most startling construction is that of consciousness itself. Consciousness seems to be continuous, at least from waking in the morning until going to sleep at night. But psychologists nowadays are inclined to think that consciousness is not a continuum but a series of pulsations, each lasting some fraction of a second. The relative durations of periods of impulses to the durations of periods between impulses vary from person to person and from time to time. Measurement of the length of these pulsating periods of consciousness is difficult and must be done by indirect means. Pulsations of consciousness sometimes correspond to eye-jerks, which pass unnoticed by most readers. One sees the line of printed words he is reading as a continuous line, but if he observes another reader's eyes he will note that eyes do not move continuously but stop, flick, stop and flick. If consciousness is a series of impulses, why do we seem to be conscious continuously? In order to be conscious of the period between moments of consciousness we would have to be conscious when we are not conscious. This is impossible. We can experience neither the period between, nor the ending, nor the beginning of a flash of consciousness. In order to experience the end of a flash, we should have to be conscious long enough to include the end within consciousness, which again is impossible. In order to experience the beginning of a flash of consciousness, we should have to be conscious already and to include the beginning of the flash of consciousness within consciousness. Thus the illusion of continuity of consciousness is a basic illusion without which experience could not be. The naive realist can not believe this.

Another basic construction is the construction of "objects." Objects seem to be "out there," even though they are not really out there as experienced. One may try the experiment of looking at his own hand, which he usually considers a part of himself. His hand seems to be out there. Try again to look at the tip of his nose. It too seems out there. Try again, with eyes closed, to imagine his own brain. If he can imagine it, the image of it too seems to be out there, not as if in the room before him, but still as an object out there in experience.

Taking leave of naive realism, we may summarize the types of criticism offered. It fails to account satisfactorily for error. It fails to take account of the extra-organic and intra-organic conditions of knowing. It fails to take into account differences in public knowing. It fails to take into account the constructed character of knowing. If these criticisms are warranted, then naive realism is untenable. The naive realist is baffled by them. But the natural urge to believe that things are as they seem is so strong that in practice he is little troubled by them.

Scientific Realism

If naive realism is untenable, then what view shall one hold? Skipping over many steps which one would normally take in the gradual process of reflection and many steps which have been taken historically in the development of reflective thought, we may summarize a view called "scientific realism." Like the naive realist, the scientific realist is also a straw man set up to represent the point of view which "the" scientist would hold

if all the assumptions and conclusions of the different sciences were synthesized into a single view of the nature of knowing. Comparing scientific realism with naive realism (see p. 1), we may summarize comparable essentials as follows. Basic throughout is a distinction between what we shall call real "things" and apparent or experienced "objects."

(1) "Objects" are dependent upon their being known; they can not endure without being experienced. "Things" are independent of their being known; they can endure without being experienced.

(2) "Objects" have qualities (properties, characteristics, attributes) which are parts of the "objects" (but not parts of "things"). "Things" have qualities (properties, characteristics, attributes) which are parts of the "things" (but not parts of "objects").

(3) "Objects" (including their qualities) are affected by, are dependent for their existence upon, are determined in their nature by, their being known. "Things" (including their qualities) are not affected merely by their being known.

(4) "Objects" seem to be real "things" but are not real "things." "Things" are not as they seem to be. Appearances are not realities and realities are not appearances.

(5) "Objects" are known directly; they are in experience. "Things" are known indirectly; they are not in experience; they are known only through "objects" which "represent" them, and which are caused by them and by other extra-organic and intra-organic conditions which happen to operate conjointly with them.

(6) "Objects" are private, *i.e.*, can not be known by more than one person. "Things" are public, *i.e.*, may be the cause of "objects" in more than one person.

Criticisms of Scientific Realism

Satisfactory as this view may seem to scientists, there are certain criticisms which should be considered.

(1) *Scientists also depend upon senses for information.* Like naive realists, scientific realists also get their experiences only through sensory channels. The scientist still seems to see the half-submerged stick as bent or broken. Each of his types of perception is equally liable to error. Thus scientific conclusions, in so far as their reliability depends upon the reliability of perception, are subject to the same criticisms as naive realism.

Price's way of putting this criticism is worth repeating.

> Every man entertains a great number of beliefs concerning material things, *e.g.*, that there is a square-topped table in this room, that the earth is a spheroid, that water is composed of hydrogen and oxygen. It is plain that all these beliefs are based upon sight and on touch (from which organic sensation can not be separated): based on them in the sense that if we had not had certain particular experiences of seeing and touching, it would be neither possible nor reasonable to entertain these beliefs. Beliefs about imperceptibles such as molecules or electrons or x-rays are no exception to this. Only they are based not directly on sight and touch, but indirectly. Their direct basis consists of certain other beliefs concerning scientific instruments, photographic plates, and the like. Thus, over and above any intrinsic uncertainty that they themselves may have, whatever uncertainty attaches to these more basic beliefs is communicated to them. It follows that in any attempt either to analyze or to justify our beliefs concerning material things, the primary task is to consider beliefs concerning perceptible or "macroscopic" objects such as chairs and tables, cats and rocks. It follows, too, that no theory concerning "microscopic" objects can possibly be used to throw doubt upon our beliefs concerning chairs or cats or rocks, so long as these are based directly upon sight and touch. Empirical science can never be more trustworthy than perception, upon which it is based; and it can hardly fail to be less so, since among its non-perceptual premises there can hardly fail to be some which are neither self-evident nor demonstrable. Thus the not uncommon view that the world which we perceive is an illusion and only the "scientific" world of protons and electrons is real, is based upon a gross fallacy, and would destroy the very premises upon which science itself depends.[2]

[2] H. H. Price, "Perception," p. 1.

(2) *Scientific concepts are human constructs.* While scientific realism attempts to take into account the fact that knowing involves some mysterious subconscious synthesis, nevertheless it can not prevent its own concepts from being thus mysteriously synthesized or constructed. Every scientific idea is a human idea, is an idea limited by the peculiar limitations inherent in the mind or minds of those who entertain it. Some scientists who are especially self-critical cease to be scientific realists. This critical attitude is exemplified by P. W. Bridgman's "The Logic of Modern Science." The laws of physics, like all scientific laws, are merely "operational ideas" which serve to explain in what way, though not why, events occur in experience. In how far regular occurrences represent real events outside of experience is not the business of science to say. Such a view seems to scientific realists as a thin pale shadow of science, not one which gives us the knowledge of reality that scientists believe they are looking for. Yet, if scientists believe they can penetrate reality, can they explain how they can do it with ideas which are subconsciously constructed and which have their momentary existences locked up within flashes of pulsating consciousness?

(3) *Scientists still have no better tests than dreamers.* This charge at first shocks scientists as absurd. But, for every test that a scientist proposes for his being awake or for the reliability of his conclusions, one may ask, "Is it impossible for him to dream that this is so?" Surely he must answer "No" and thereby admit the impossibility of proving his position any better than a dreamer might.

(4) *Scientific realists unwittingly claim impossible transcendence.* Admitting that "objects" are private, scientific realists themselves fall into the egocentric predicament. Only private "objects" are experiencible. How then is it possible to know either that there is an unexperienced real world or what it is like? When scientific realists claim that they know that there are public "things" and that they are electrons, atoms, molecules, etc., they claim to know the existence of and, within limits, the nature of unexperiencible things. How can knowledge which is locked up, so to speak, within moments of conscious experience transcend those moments and reach out, so to speak, into the unreachable real world to know it? Knowledge of reality seems to presuppose experience of the unexperiencible. To be real is to be independent of experience, so inherent in scientific realism is the necessity of experiencing what, by the very nature of experience, can not be experienced.

(5) *Scientists still fail to explain why "objects" appear as if they were "things."* The mystery of why appearances seem real remains a mystery to the end. The scientific realist is beset with a belief in the reality of the objects he talks about. Even though he is constantly critical, can he ever conceive a real atom without conceiving it as real? Why, if one's conceptions continue to be within him, does he conceive objects as if they were really "out there"?

No attempt has been made in this article to give any final answer to the question, "What is knowledge?" Two types of answers have been presented and criticized. It is hoped that the reader has been aroused sufficiently to investigate other types of answers such as rationalism, idealism, scepticism, agnosticism, critical realism, neo-realism, pragmatism, positivism or the author's proposed "tentative realism."

RESPONSES IN AN ASSOCIATION TEST

By the Late Dr. RUDOLF PINTNER

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THE association test in psychology consists of the presentation of a stimulus word which elicits another word as a response from the subject. It is probably one of the very oldest of psychologist's tests. It has been used in abnormal, criminal, educational and business psychology in many ways.

In 1933 this writer reported in this journal[1] the responses of students to the stimulus, "Think of the name of a president of the United States." This was one item in a written group association test given annually to groups of students, beginning in 1925. This test has been continued, and we now have results from 1925 to 1941 for 6,071 individuals.

TABLE I

RESPONSES TO THE STIMULUS "THINK OF THE NAME OF A PRESIDENT OF THE UNITED STATES"

Response	Number	Per Cent.
Washington	1,343	22.1
Roosevelt	1,288	21.2
Lincoln	856	14.1
Wilson	820	13.5
Hoover	538	8.9
Coolidge	429	7.1
Harding	176	2.9
Grant	95	1.6
Jefferson	90	1.5
Adams	73	1.2
McKinley	69	1.1
Taft	53	0.9
Cleveland	50	0.8
Garfield	45	0.7
Jackson	40	0.7
Monroe	27	0.4
Madison	16	0.3
Harrison	12	0.2
Johnson	8	0.1
Hamilton	5	0.08
Hayes	5	0.08
Polk	5	0.08
Van Buren	5	0.08
Buchanan	4	0.07
Taylor	4	0.07
Arthur	3	0.05
Pierce	3	0.05
Tyler	3	0.05
Fillmore	2	0.03
Franklin	1	0.02
Lee	1	0.02
No Response	2	0.03
Total	6,071	100.01

[1] R. Pintner, SCIENTIFIC MONTHLY, 36: 523–526, June, 1933.

The main conclusions in our previous article seem to be borne out by the data accumulated since it was written, and some of the suggestions offered then have been strengthened, as we shall see.

Table I shows all the responses made by the 6,071 individuals. Practically all these were college students, with the exception of 385 W.P.A. workers tested in 1937, most of whom had no college education. The list in Table I includes all the presidents of the United States, and in addition three famous men who have not been president: namely, Hamilton, Franklin and Lee. The two latter have been mentioned only once each, but Hamilton is named more frequently than several actual presidents. In this test it is not possible to distinguish between two presidents having the same family name, as in the case of the two Roosevelts, the two Adamses and the two Harrisons.

The whole list falls into three divisions. At the top we have the first four most frequently mentioned, accounting together for 70.9 per cent. of the responses. Then we have three presidents very recently in office, two of them actually in office during some of the years this test was given. These three responses account for 18.9 per cent. of the total. Down to this point, therefore, the first seven responses are responsible for 89.8 per cent. of all responses. After these we have the long list of other responses, no one of which amounts to more than 1.6 per cent. This long list of "also rans" accounts altogether for only 10.2 per cent. of the total responses.

Three main factors seem to me to be at work in explanation of the most common responses, that is, the first seven names on our list. One factor is that which

causes the great majority of the common responses in all our association tests; namely, the habits formed in hearing, reading, speaking and writing. One word is linked to another because of these habits.[2] This is very likely the main factor at work in the responses "Washington" and "Lincoln." These two names have been linked to "president of the United States" on countless occasions, and they emerge promptly at the given stimulus.

Another factor at work is recency. Although by no means as strong as the preceding factor, it explains some responses in all association tests. If we have just been reading the life of Henry VIII of England, we may write the word "Henry" to the stimulus word "king" in an association test, although the most common response by force of habit to this stimulus word is "queen" (50.1 per cent. of all responses in my test). With reference to our presidents, this factor of recency is potent in the responses "Hoover," "Coolidge." "Harding" and to some extent "Roosevelt." Three of these individuals have been in office during the time the test was being given, and one, Harding, just previous to that time. Recency is also very probably one of the factors at work in the response "Wilson," but another more potent factor, to be discussed presently, is also at work. The effect of recency can be seen most clearly in the responses "Hoover" and "Coolidge." Here are the average annual percentages for the years in office and for the succeeding four-year periods:

[2] E. L. Thorndike, *Jour. Applied Psychol.*, 16: 247–253, 1932.

	1925–28	1929–32	1933–36	1937–40
Coolidge	16.5	5.2	3.2	1.5
Hoover		21.2	8.4	4.7
Roosevelt	4.6	3.4	38.3	48.0
n	1,654	1,866	630	1,669

The response "Roosevelt" is complicated. As we can see from the above, a small percentage of the responses refers to Theodore Roosevelt. The sudden increase in percentage during the incumbency of Franklin D. Roosevelt is due to a combination of recency and another factor.

This brings us to the consideration of the third main factor. This is the feeling tone or emotional aura surrounding a given stimulus. For example, if one feels keenly about the danger of drinking alcoholic beverages, the response to the stimulus word "whiskey" may be influenced by this emotional setting. In my experiment about 1.6 per cent. of the responses seem overtly to indicate a strong feeling against whiskey. Such responses are "bad," "harmful," "poison" and the like. Not all strong emotional tone issues in such overt responses, so that it is impossible to measure it with any degree of accuracy. Ordinarily this factor of emotional tone is the weakest of the three influences we have described.

The influence of this factor upon two of the responses to "president of the United States" seems to me to be nicely demonstrated in the responses "Wilson" and "Roosevelt" during the years 1925 to 1941. During the lifetime of most people now living, no other presidents have stirred up so much emotional agita-

TABLE II

CUMULATIVE PERCENTAGES OF RESPONSES TO "PRESIDENT OF THE UNITED STATES"
MEAN FOR EVERY TWO YEARS

	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41
Roosevelt	5.8	4.3	4.1	3.9	5.0	9.1	16.1	19.9	21.2
Wilson	22.6	21.1	19.9	18.4	17.9	16.7	15.1	14.1	13.5
Washington	27.2	27.7	26.1	25.1	25.2	24.4	22.9	22.5	22.1
Lincoln	13.7	15.6	16.0	15.7	15.4	15.0	14.2	13.8	14.1

TABLE III

CUMULATIVE PERCENTAGES OF RESPONSES TO "AN OUTDOOR GAME" MEAN FOR EVERY TWO YEARS

	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41
Tennis	32.5	35.4	34.6	33.8	33.7	33.2	33.5	33.4	32.8
Baseball	27.6	29.2	28.6	30.0	29.6	29.3	28.9	28.5	28.9
Football	14.9	10.9	12.2	12.0	11.9	12.1	11.4	11.6	11.6
Golf	8.1	9.0	9.5	9.4	9.4	9.2	9.2	9.0	8.7

tion as these two men. In the case of each of them, many people feel keenly. They "take sides," either for or against. They either love or hate. With Wilson this effect is on the wane; with Roosevelt it is at present very strong.

This waxing and waning can be seen in Table II. This table gives the cumulative percentages; that is, the percentages of the total number of responses up to and including any given year. These cumulative percentages were calculated every year. In order to condense the material, Table II shows the mean of these percentages for every two years (except for the last period, 1941). The response "Roosevelt" is stationary until 1933–34, and then begins a spectacular rise—spectacular because the percentage of such responses has to overcome the load of non-Roosevelt responses accumulated prior to that period. The two factors of recency and emotional tone continue to boost the percentage in 1941 up to the stable "Washington" response, which has been steadily accumulating during the whole period. The response "Wilson" shows a steady decline from a high point in 1925–26, due to the rapid waning of emotional tone. Contrasted with these two responses which show marked changes are the responses "Washington" and "Lincoln," which have remained practically stationary during the whole period. The primary factor at work here is undoubtedly the first fact described, namely, habitual association between stimulus and response.

This analysis of the responses to one stimulus word over a period of years has been chosen to show how contemporary happenings may influence our associative trends. The association test may act as a sort of miniature social barometer. As a contrast to the ups and downs in the responses to the stimulus "president of the United States," I give in Table III biennial cumulative percentages of the responses to the stimulus "think of an outdoor game." Here the forces of associative habit have reigned supreme during the whole period. Nothing has happened to group thinking about this stimulus to interrupt the common habitual type of response. An individual here and there in the group may be influenced in regard to his particular reaction because of recency or emotional tone, but the group as a whole from year to year shows no such influence. The four typical outdoor games for adults in this country at this time are the four listed in our table.

This stability of group responses from year to year is the outstanding characteristic for most stimuli in the usual association test. The forces of habit are very similar for most individuals in a country such as ours, and this similarity leads to a surprising uniformity in the frequency of responses from year to year. The changes in frequency, which we have noted in connection with the responses to "president of the United States" are indicative of wide-spread factors at work among many individuals in the group. The emotional factor may at times become as potent as or more potent than the habit factor, as we have noted in the response "Roosevelt," but the habit factor is there ready to take over as soon as the emotional tone decreases.

BOOKS ON SCIENCE FOR LAYMEN

THE LIFE OF NATHANIEL BOWDITCH[1]

THERE has been no time in the past when so many young Americans were being taught the principles and practices of navigation. It does not make much difference if these students are aimed at the Navy, the Merchant Marine, or the Aircorps, for they will before long all meet up with the mythical volume "Hydrographic Office Publication No. 9" or "Bowditch's American Practical Navigator." The name of Nathaniel Bowditch has become a legend in the annals of American navigation and it is fortunate indeed for the young scholar, as well as for his instructor, that there is now available an authoritative biography of the life of the man whose name has become a household word in navigation.

Nathaniel Bowditch was born in Salem, Massachusetts, in 1773, the fourth child in a family of seven. His father, Habakkuk Bowditch, was, as Mr. Berry puts it rather nicely, "remembered by his pastor for two things; his knowledge of the Scriptures and his extraordinary consumption of rum." Life was not easy for the Bowditches. For a while they lived in a little house at Danvers, a few miles outside of Salem, but they returned to Salem again, and it was in Salem that Bowditch grew up to become one of the most respected citizens of his country. At the age of twelve Nathaniel Bowditch went to work as an apprentice clerk in a ship's chandlery. He received little formal schooling, but with the aid and encouragement of the apothecary, Nathan Read, and two of the local ministers, he succeeded in training himself thoroughly in mathematics and navigation. When, in 1795, Bowditch went to sea he had already acquired a knowledge of mathematics that was equal to that of any other man in the colonies at that time. His first trip as a supercargo on Captain Prince's *Henry* took him to the "Isle de Bomton" (now Réunion), and it was on this journey that Bowditch's interest in the practical side of the art of navigation was awakened. Other journeys took him to the East Indies and to the Philippines, in the beginning again as a supercargo, later as the captain of his own ship.

Urged on by the publisher Edmund M. Blunt, Bowditch was led to correct and edit an American edition of John Hamilton Moore's "The Practical Navigator." Bowditch found this volume to be so full of errors that it would have been folly for a captain to chart his course with the aid of Moore's volume. Bowditch wished to create a book of his own, one that would be literally free from errors and so written that every sailor could understand and use it. It is told how Bowditch tried out his scheme on the crew of one of his ships and progressed to the stage where every member of the crew, including the cook, knew how to determine his ship's position from celestial observations. Bowditch's "The New Practical American Navigator" became right away a popular volume and it was not long before a copy was to be found in the chest of every seafaring man.

The word of Bowditch's fame had begun to spread. In 1799 he was elected a member of the American Academy of Arts and Sciences and in 1802 he received the honorary degree of Master of Arts from Harvard University. His career as a sea captain ended in 1803, with his spectacular landfall and safe arrival during a snowstorm in the harbor of Salem on the evening of December 25th, an incident that will always remain a classical example of the use of "dead

[1] *Yankee Stargazer. The Life of Nathaniel Bowditch.* Robert Elton Berry. Illustrated. xi + 234 pp. $2.50. 1941. Whittlesey House.

reckoning" by a great navigator. At the age of thirty Bowditch could look back on an honorable career at sea. He was the acknowledged master navigator and his reputation as a mathematician was great.

For us of the twentieth century it is not easy to understand why Bowditch chose at this stage a career in the rather dull and prosaic field of marine insurance. For almost two decades in Salem, and after that until his death in 1838 in Boston, he was during the daytime a skillful executive in marine insurance and at night a mathematician by avocation. His mathematical efforts were mainly concerned with the translation of Laplace's monumental "Mécanique Céleste." His was much more than a simple translation for Bowditch, with his meticulous care and keen analytical mind, added many explanatory notes to the original manuscript. And yet when one reads of Bowditch's life, one can not help but feel some disappointment that the young man of thirty did not see before him a grand opportunity as a creative scientist. Perhaps Bowditch did not have great creative powers and his strength may well have laid wholly in his very special analytic ability. We can, however, only regret that Bowditch in the second half of his life did not attempt to be himself one of the great men of mathematics or astronomy rather than to have remained the brilliant interpreter of those who came before him.

Mr. Berry has written a good book; I would almost say that it is as carefully written as Bowditch would have liked to see it done. There is little reason to doubt the accuracy of its sources; it is fully documented and well written. The only criticism that I wish to make is that the book in spots lacks warmth and understanding. One might almost have wished that occasionally Mr. Berry could have let himself go and that he might have forgotten about historical accuracy to tell us more about why at the age of thirty Bowditch chose to lead what seems to a twentieth century astronomer a prosaic life when the heavens were opened before him!

B. J. Bok

A BIOLOGIST LOOKS AT MAN[1]

This book, covering a wide range from Philosophy to Sociology through Endocrinology, Religion and "Sex," should be of interest to the general public, if not to the professional psychologist. The thesis of the first chapter appears to be that biology should take over the field once known as "social psychology." This suggestion is quite in line with the original meaning of the word *bios*, which signified "life" in the social-economic sense, not the zoological. Now that "social psychology" has become disreputable because most of the group which, up to December 7, 1941, called themselves "social psychologists" were unable to understand the forces which had been for nearly fifteen years preparing this war, and busied themselves with trifling problems, this might be an appropriate time for non-psychologists to take over the field.

The defense of science in the second chapter seems to the reviewer needlessly to place science in the prisoner's dock; but wisely avoids critical points and follows conventional lines, although the author lays himself open to question by claiming social progress in matters such as child labor and the status of women as scientific accomplishments. The question would be: What science?

The third chapter, on "Man's Place in Nature," leads through a review of anthropological and zoological data, up to a sound and well-formulated rebuke to those who have regarded man as an infinitesimal speck in the vast universe.

[1] *Speaking of Man: A Biologist Looks at Man.* Michael F. Guyer. 321 pp. $3.50. October, 1942. Harper and Brothers.

The fourth chapter, on "The Rise of Intelligent Behavior," is a somewhat hasty survey of the field which is commonly called physiological psychology, taking account to some extent of the progress which psychology had made in this field from the traditional basis of assumptions and theories inherited from the physiologists. The fifth chapter, on "Managing our Minds," is a venture into the field of adjustment psychology, implemented from popular psychology and pseudo-psychology. The sixth chapter, on "The Endocrine Control of the Body," appears to the reviewer to be an excellent presentation, by an expert, of important physiological aspects of endocrine function. In considering the effects of hormones on the emotions, the author neglects, as do most endocrinologists, the effects of emotions on the endocrine balance—a topic which is becoming more and more important to psychologists in the field of adjustment.

The seventh chapter deals with "sex" in the confused meaning of that multivalent term which is usual in psychoanalytic and other popular disquisitions. As in most popular articles and books on sex a limited selection of facts is put before the reader, who (if a layman) is not able to supply the omitted material which is necessary for interpretation, or to distinguish the fact from the fiction.

The last three chapters deal with "Democracy as a Biological Problem," "The Educated Failure," and "Man's Search for the Ideal." Although nothing is presented in these chapters which would not be familiar to the educated layman, the author's selections of doctrines and arguments are clearly presented and should be interesting to readers not too sophisticated. The last chapter includes a defense of religion, with misconceptions of certain religions cited, and a defense of a theory of evolution. The form of evolution defended is not clearly indicated; but so far as the reviewer can judge, it is the popular theory which makes evolution analogous to the slow filling-in of the words of a cross-word puzzle, the definitions for which are assumed to have been fixed, unchangeably, in the beginning of the world.

There are some points which might be questioned as regards their validity, their implications or their consistency with other statements, but the reviewer does not feel inclined to criticize details in a popular book.

KNIGHT DUNLAP

FACTS AND THEORIES ABOUT BIRD MIGRATION[1]

OF all the aspects of bird study, migration is probably still the one that interests the greatest number of observers, and in spite of the vast amount of observational data on record, is still one of the least solved, most obviously mysterious of all bird behavior problems. The fact that, in war-torn England, a revised edition of Thomson's compact little book should be issued (and it would not be published unless there was an assumed demand for it) is a clear indication of migration's continuing interest for natural-history minded folk. The book is essentially a reprinting of the first edition of 1936 with very few minor changes and additions (for instance, it has thirteen maps as compared with ten in the first edition). The type is smaller and the number of pages correspondingly reduced from 224 in the 1936 edition to 192 in the present one. [A publisher's note on the back of the fly leaf states that, "the paper and binding of this book conform to the authorized economy standard."]

The book is divided into four main parts, each containing three chapters. They are: 1. Introduction to Migration, with accounts of the study of migration, the different types of migratory be-

[1] *Bird Migration.* A. Landsborough Thomson. Revised edition. 192 pp. 6/-. 1942. H. F. & G. Witherby, Ltd. (London).

havior, and the phenomenon of migration in its broad aspects; 2. Certain aspects of migration, with discussions of the directions, the seasons, and the methods of migration; 3. General Features of Migration, involving accounts of immensity, its complexity, and its regularity; and, 4. Theories about Migration, with the discussion grouped under the topics of the utility and causes of migration, and the mechanism of guiding during migration.

A book of this sort and size is designed for the general reader, and not for the advanced student. In this it is very successful and merits a new edition. It is characterized by accuracy and critical caution, and should serve, as did its predecessor, to give information and pleasure to a large number of people.

HERBERT FRIEDMANN

THE AMATEUR SCIENTIST IN PHILADELPHIA[1]

THE money profit motive has been overemphasized in this modern world. Human beings do not do things primarily for dollars. They do them because they are interested in them and want to do them. Much of the important work of the world is unpaid in cash but paid in pleasure.

The American Philosophical Society's Committee on Education and Participation in Science, with grants from the Carnegie Corporation, carried on for three years one of the most exciting inquiries and demonstrations of recent years concerned with the public participation in science, not as spectators but as practitioners. W. Stephen Thomas, who steered this experiment, tells the story of its success and its background in "The Amateur Scientist."

In Philadelphia, rich in scientific history, fortunate in educational and scientific institutions and museums, and mellowed by an atmosphere conducive to contemplative inquiry, there were discovered by Mr. Thomas some 32,000 scientists-for-the-fun-of-it with societies and informal groups that number nearly 300. We hear much about the professionals, the professors, the science taught in school and college, but we have heretofore heard little about the amateur. We are prone to forget that Benjamin Franklin, whose influence hovered over almost everything scientific in the City of Brotherly Love, was an amateur in science although certainly no novice.

A quartette of specialists, a helpful committee and a small central staff brought to light and gave some stimulation and unity to these serious hobbyists. There were sample and demonstration research projects: When the wild flowers bloom; what tree rings show about the climate of the past; how to mark snakes, frogs and turtles to keep tab on them; and how to probe the upper atmosphere with radio waves. There was sufficient prospecting and assaying to show that there is much scientific gold in those nights, days-off, and Sundays of the expert amateur in science.

You would expect school teachers, pharmacists, physicians, chemists, engineers, to be amateur scientists in Philadelphia, but would you have guessed that there were bankers, business executives, clerks, mail carriers, printers, pattern makers and a hundred other occupations among them, including a professional dancer, housewives by the score, those who have retired and some unemployed?

This extensive interest in science as a serious hobby is not limited to the type city of Philadelphia. Probe beneath the surface of any city or town and you will be sure to find enthusiastic and competent scientific amateurs. The Philadelphia story demonstrates that this is a neglected field, worthy of cultivation by a local institution that has motivation and resources to activate, counsel and guide the latent or unorganized abilities.

[1] *The Amateur Scientist.* W. Stephen Thomas. Illustrated. 291 pp. $3.00. 1942. W. W. Norton and Company.

Professional societies in various fields would be highly justified, in the future when peace gives them time, to integrate this work with their present professional activities, cooperating in a national movement. The way has been blazed for the future by the Philadelphia experiment.

The encouragement of amateur science for adults is as important as the stimulation of scientific hobby activity in the high schools, which is well under way by the national organization of Science Clubs of America administered by Science Service. If the appreciation and understanding of science and its methods can be brought to the attention of the millions as they go through grade schools, high school and college, if they have the opportunity of actively carrying on their interests in later life, even if they choose other means of earning a living and serving the world, then there is a good chance that the world will conduct its affairs more sanely as the number of scientifically oriented people in it increase.

Here is a practical blueprint for future activity when the war is won and we begin to win the peace. Whether we get a chance to build it will depend upon how soon we can start and with what vision and enthusiasm we begin this mobilization of science for all who volunteer.

WATSON DAVIS

HUMANIZING SPIDERS[1]

In the forenoon of September 22, Spinoza died.

This Spinoza was not a philosopher, but a tarantula. In company with Beautiful Lady, Silver Queen and other spiders with personalities, she is described and discussed by Miss Emans in this entertaining book.

[1] *About Spiders: Introducing Arachne.* Elaine V. Emans. Illustrated. xix + 183 pp. $2.50. 1940. E. P. Dutton and Company.

There are nineteen chapters, beginning with the time when Miss Emans became snared by spiders, with notes on anatomy and on behavior, based on long hours of careful observation of numerous individuals, some at liberty in the garden and house, others confined to observation quarters. There is a chapter on their economic value and another on their enemies, the most commonly observed of which is the neat housewife with the long-handled broom, annoying the author, who admires the finer qualities of spiders.

The book is nicely illustrated by photographs and pen and ink sketches. A short chapter, "Oddities and Ends," concludes what is an informative and readable account of a group of our much misunderstood neighbors.

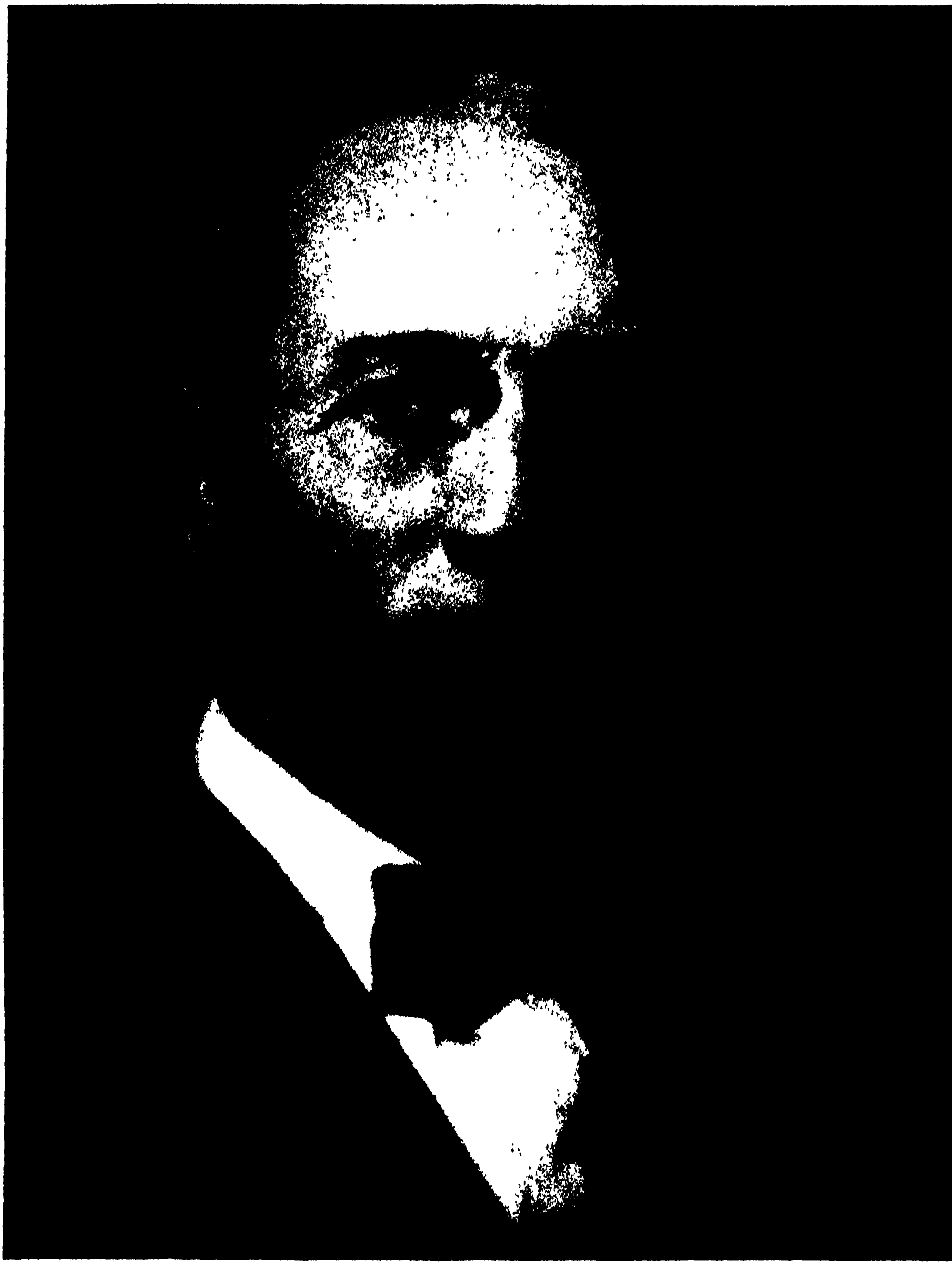
W. M. MANN

A SURVEY OF BIOLOGY[1]

THIS book is exactly what its sub-title indicates--a survey of various fields of biology. The material which it covers is arranged in a series of chapters, each of which attempts to discuss one branch of the field. The author has succeeded very well in relating the separate fields and in showing the bearing which each has on the others. Although such treatment is bound to be somewhat disconnected, as a survey this book is to be recommended, for it covers many fields and it presents an immense amount of material in a relatively small space. It is put out by planograph, and some of the pictures which would be excellent as photo-engravings are not any too satisfactory, but the wealth of line drawings and diagrams is a real addition to text material. Its value as a text depends entirely on the way one evaluates survey courses in general.

D. B. YOUNG

[1] *Life Science.* M. W. de Laubenfels. Illustrated. i + 320 pp. $3.75. 1941. Laubenfels.



GARY NATHAN CALKINS

THE PROGRESS OF SCIENCE

GARY NATHAN CALKINS, 1869–1943

THE death of Gary Calkins on January 4, 1943, removes yet another of the "old guard" of science from our midst. Not only was he scientist in the best tradition, but also a man who attracted hosts of friends, so that his passing is a deep personal loss to many, both old and young.

Indiana was his native state, but he spent his student days at the Massachusetts Institute of Technology, where he graduated in 1890 in biology with the degree of B.S. Thereafter his life was devoted to a scientific career. Under the influence of William T. Sedgwick he early became interested in the Protozoa, especially with reference to their part in pollution of water supplies, and was assistant biologist to the Massachusetts State Board of Health from 1890 to 1893; during the same period he was also lecturer in biology at the Massachusetts Institute of Technology. In 1893 he transferred as a student of Edmund B. Wilson to Columbia University, which became his professional home for life from the time of his arrival there. Appointed tutor in biology in 1894, he passed rapidly through the academic grades to that of professor in 1904. In recognition of his ruling interest he was given the special title of Professor of Protozoology in 1906, the first to receive the title in America. He retired as "emeritus in residence" in 1940. Columbia University conferred the honorary degree of Sc.D. on him in 1929 in addition to the Ph.D. degree in 1898. Among other honors he was elected member of the National Academy of Sciences in 1919.

Following his preoccupation with public health problems at the Massachusetts Institute of Technology, which terminated in 1893, the influence of Edmund B. Wilson, the great master of "the cell in development and inheritance," diverted his interests to problems of karyokinesis with special reference to spermatogenesis in the earthworm (1895) and later in the large marine phosphorescent protozoa, Noctiluca (1898). The latter study marked his return to Protozoa, but now mainly on account of their special advantages as material for general biological problems. He did not, however, lose the special in the general, but throughout his life continuously displayed his interest in Protozoa as organisms of a special phylum by significant publications which displayed his comprehensive knowledge of the whole group.

He began his general studies by an examination of Maupas's classical works on senescence, conjugation and rejuvenescence in Protozoa (1888–1889) and of August Weismann's interesting conception of immortality of these organisms (1891). His experiments on *Paramoecium caudatum*, begun in February, 1901, required daily attention for a period of two and a half years. He improved on Maupas's methods in various respects, but especially by keeping exact account of the number of generations by division; this involved isolation of individuals in new culture slides with fresh medium after two or three divisions at the most, that is, about every other day. He found that well-marked periods of depressed vitality occurred at about six-month intervals with less evidence of depression at about three-month intervals, but that these could be overcome by suitable changes of the culture medium, a result that he compared to artificial parthenogenesis, then a new subject. However, there came a time when all treatments failed and the best series finally died out in the 742d generation. His results led him to accept the idea that growing old is a natural phenomenon in Protozoa as well as in Metazoa,

and to reach the conclusion "that the indefinite continuation of life without conjugation is improbable" (1904); in this he was in substantial agreement with Maupas.

He published numerous later papers on life histories of Protozoa, generally with these problems in mind. They took a different form when L. L. Woodruff of Yale University, a former student of Calkins, undertook a day by day study of naturally occurring rhythms in *Paramoecium aurealia* and, in conjunction with Rhoda Erdmann (1914), discovered the phenomenon of "endomixis," a periodic reorganization of the entire nuclear apparatus within single individuals which restores the upper level of the rhythms. Woodruff's cultures of this species were continued to 5,250 generations up to 1915, over a period of eight years, without conjugation or the use of artificial stimuli. Calkins's final statement of the problem in 1934 included endomixis along with conjugation, encystment, reorganization during division, and environmental and metabolic conditions as factors controlling longevity in protozoan protoplasm.

His published researches are a lasting memorial. He was also an enthusiastic and successful teacher and has left distinguished followers who received their inspiration from him to carry on his tradition. His books, products of his research and teaching, were: "The Protozoa," 1901; "Protozoology" (based on lectures before the Lowell Institute in 1907), 1909; "Biology," 1914; "Biology of the Protozoa," 1926 and 1933.

Outside of his more strictly institutional activities Calkins was in great demand. There is space to mention only a few examples. Thus from 1902–1908 he served as consulting biologist to the New York State Cancer Laboratory in Buffalo; from 1919–1921 he was president of the Society for Experimental Biology and Medicine. In 1926–1927 he was director of the University Union in Paris, where he had the opportunity of promoting the interests of foreign students, especially American, in that city and throughout France. But Calkins's principal scientific activities outside of Columbia University were in connection with the Marine Biological Laboratory at Woods Hole, Massachusetts. His connection with the Laboratory dated back to 1893, and he established a summer home there about 1910. After that time he was present for all the summer sessions except for one year in Europe. He was a member of the Corporation for 39 years, Trustee for 30 years, Clerk of the Corporation for 17 years, Secretary of the Board of Trustees for 12 years; he was also investigator there for 35 years, a member of the research staff for 31 years, head of the course in Protozoology for 22 years. His devotion to the Marine Biological Laboratory, his second institution, was unbounded.

He will be remembered for what he was no less than for what he did. Perhaps his most striking personal characteristic was a special quality of lovableness displayed in his relations to his family, his friends and his professional associates, both contemporaries and students. That his gifts of human kindness were reciprocated was shown by the portfolio of about two hundred letters addressed to:

Gary Nathan Calkins
Philosopher in Little Things
and Friend

from his students and friends, presented to him in 1941 after his retirement, expressing their esteem and appreciation. That this testimonial took such a personal form, rather than the more usual form of a congratulatory volume of scientific contributions from former students and associates, is eloquent evidence of the respect and affection that Calkins drew to himself.

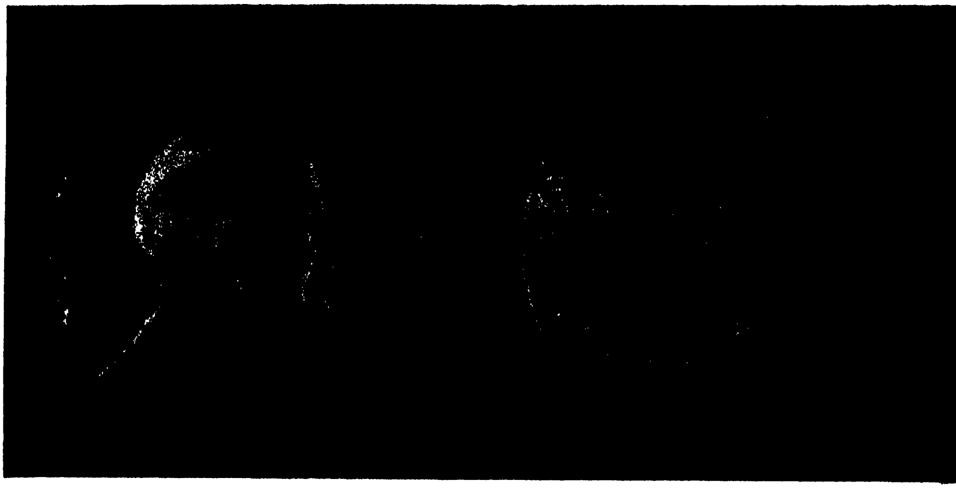
FRANK R. LILLIE

CHARLES FREDERICK BURGESS, EDWARD GOODRICH ACHESON MEDALIST

At its fall convention in 1942 the Electrochemical Society bestowed on Dr. Charles F. Burgess the Acheson Medal and Prize, the highest honor in electrochemistry.[1]

Dr. Burgess' world-wide reputation is based largely on his contributions to the modern dry cell, the "Burgess Battery." When Dr. Burgess originally approached the dry battery problem, forty years ago, there were then so many contradictory reports as to the electrochemical reactions involved and so many complications inherent in the manufacture of a good dry battery that only an investigator with a vision and insight such as Burgess possesses would have considered the problem worth investigating. But characteristic of the Burgess experimental approach and his untiring enthusiasm, the difficulties involved and the causes for irregular battery behavior were solved, one by one, so that within a few years the battery specifications adopted by the National Bureau of Standards were largely based on Burgess' findings.

[1] Previous recipients of the award are Edward G. Acheson, Edwin F. Northrup, Colin G. Fink, Frank J. Tone, Frederick M. Becket and Francis R. Frary.



THE EDWARD GOODRICH ACHESON MEDAL

Another of Burgess' pioneering researches is that on electrolytic iron of almost 100 per cent. purity. All iron electro-deposition baths developed previous to Burgess produced deposits that were either very thin or dark, rough and powdery. Over three tons of pure electrolytic iron were produced in the pilot plant in the Burgess laboratory at the University of Wisconsin. This iron served as the basis of some 1,000 alloys which Burgess tested and otherwise studied.

An outstanding physical property of electrolytic iron is its high permeability and relatively low hysteresis loss. Accordingly, the Western Electric Company at Hawthorne, Illinois, installed a large electrolytic iron plant using the Burgess formula and manufactured rings of electrolytic iron for the Pupin coils used in transatlantic telephony. This Hawthorne plant continued to operate for many years until the advent of the nickel-iron alloys, permalloy and mμ metal, whose magnetic characteristics were even superior to those of pure iron.

Aside from the interesting magnetic qualities and consequent applications of electrolytic iron, Burgess found another property that has led to a new use for this pure iron during recent years. He demonstrated that electrolytic iron can be made very brittle "due to occluded hydrogen." This brittle product is today ground to a fine powder and, with certain alloying additions, is used to make intricate gears and other iron parts more easily manufactured by powder metallurgy methods than by casting or machining. The spent pickling solutions of the steel mills are cheap and "inexhaustible" raw material for electrolytic iron.

Many pages would be required to present the numerous scientific and industrial accomplishments of the medalist. The wide scope and large diversity of the problems and products of the laboratories directed by Dr. Burgess during the past forty years are evidenced by the following partial list: purification of drinking water, standardization of city gas, copper-beryllium alloy springs, aluminum rectifier, copper-bearing steels, sound-absorbing materials, conversion of swamp weeds into useful products, clay building blocks, rubber dispersions, gas filters, sterilizing liquids, corrosion of strained metals, etc.

Dr. Burgess was born in Oshkosh, Wisconsin, on January 5, 1873. His alma mater is the University of Wisconsin (B.S. 1895; E.E. 1898; Sc.D. *honoris causa*, 1926). He taught at Wisconsin for eighteen years. When he was twenty-seven years old Dr. Burgess introduced a course in electrochemistry, one of the first of such courses in America.

The C. F. Burgess Laboratories were founded in 1910 at a time when industrial research had not been generally accepted. The original capital investment totalled $9,000. By 1923 this had increased to $900,000 through earnings and sales of stock.

Dr. Burgess, now past seventy, continues his active interest and participation in the C. F. Burgess Laboratories and in the half-dozen subsidiary companies. At his winter home on Burgess Isle near the west coast of Florida he maintains a well-equipped laboratory where he enjoys testing out ideas that often seem fantastic or impossible to the lay mind.

Dr. Burgess once wrote: "If business incidents are met by the chemist as patiently and cheerfully as he meets the problems involved in laboratory research, the chances for pleasure and profit from his business are excellent."

COLIN GARFIELD FINK

THE YALE LABORATORIES OF PRIMATE BIOLOGY

THE immediate occasion for this note is an announcement by Yale and Harvard Universities of their cooperation in the furtherance of primate research by jointly operating the laboratories at Orange Park, Florida, which heretofore, as the Yale Laboratories of Primate Biology, have constituted a department of the Yale School of Medicine. In this cooperative enterprise the universities have the financial assistance of the Rockefeller Foundation, the Carnegie Corporation, and the Samuel S. Fels Fund. It is stated that the name has

ADMINISTRATION BUILDING, YALE LABORATORIES OF PRIMATE BIOLOGY

been changed to Yerkes Laboratories of Primate Biology, Inc., and that the corporation consists of three representatives of each university.[1]

Responsibility for research and educational activities in the establishment will rest with Director Lashley and a Board of Scientific Directors consisting of: Dean Francis G. Blake, Yale School of Medicine; Leonard Carmichael, President of Tufts College; George W. Corner, Director, Department of Embryology, Carnegie Institution of Washington; Derek E. Denny-Brown, Professor of Neurology at Harvard; Frederick L. Hisaw, Professor of Zoology at Harvard; William H. Taliaferro, Professor of Parasitology at the University of Chicago; and Professor Yerkes of Yale.

This undertaking had its origin in the Primate Laboratory of the Yale Institute of Psychology, in 1924. Five years later, with the support of the Rockefeller Foundation, Yale established the Anthropoid Breeding and Experiment Station at Orange Park, Florida. Since its opening in 1930 the Station has developed steadily and, in large measure, the original objectives have been achieved. The site of some two hundred acres has proved almost ideally suitable for the project and a number of permanent buildings have been erected, the most recent of which are a modern laboratory building and quarters for monkeys.

Starting with four chimpanzees as nucleus of an anthropoid breeding colony, all of which had been born in Africa and were of unknown age and life history, the Laboratories had in 1942 a col-

[1] From Harvard, James B. Conant, President, William B. Claflin, Jr., Treasurer, Henry L. Shattuck, Fellow of Harvard College; from Yale, Charles Seymour, President, Thomas W. Farnam, former Associate Treasurer and Comptroller, and Carl A. Lohmann, Secretary. Dr. Karl S. Lashley, Research Professor of Neuropsychology at Harvard, has been appointed Director of the Yerkes Laboratories and Dr. Henry W. Nissen, Associate Professor of Psychobiology at Yale, Assistant Director. Dr. Yerkes, as Director Emeritus, continues as Professor of Psychobiology at Yale.

A VIEW OF THE LABORATORY BUILDING

SHOWING THE OPEN CORRIDOR CONNECTING IT WITH THE ADMINISTRATION BUILDING.

A NEAR VIEW OF ONE END OF THE ANIMAL QUARTERS BUILDING

ony consisting of about fifty individuals. There have been nearly that number of births in the Laboratories.

Dr. Lashley in reviewing and appraising the history of this project points to the following three initial objectives as essential to its successful development.[2] "Foremost of these was the development of methods for the breeding and rearing of healthy stock and the establishment of a colony of known age and history. This aim has been fully achieved. A second objective was a broad psychobiological study of the chimpanzees, for the light which it might throw upon the origins of human biological and social traits. Such a study can never be completed . . . but the reports from the Station now present an integrated account of the physiological and psychological characteristics of the chimpanzee which is more nearly complete than that available for any other animal except, perhaps, the rat. A third objective in the original plan was to determine the suitability of the chimpanzee as research material for the investigation of various questions of physiology, psychology and medicine, and to develop the lines of investigation in which the animals could be used to best advantage. Several such fields of research for which the chimpanzee is uniquely adapted have been defined and work in them initiated. Priority of the breeding program thus far has restricted work mainly to problems which did not require sacrifice of the animals. The chimpanzee colony has now reached the maximum size which can be maintained with the facilities of the Station. An adequate supply of animals for more radical experiments may be anticipated"

Looking beyond the present vantage ground of achievement into the future of research with the higher primates, Dr. Lashley concludes that "The general fields of investigation which promise immediate, valuable results at the present stage of development of physiology and

[2] Quoted from an unpublished "Program for Research at the Station."

A GLIMPSE OF THE VEGETATION ABOUT THE ADMINISTRATION BUILDING

psychology are the 'dynamics' of behavior and the nature of 'intelligence'."

The new director has laid out a plan of research which includes several groups of related psychobiological problems. Notable among them are (1) ontogenetic and phylogenetic studies of growth and intellectual capacities in the primates; (2) analysis of sexual behavior in its relations to neural and endocrine functions; (3) descriptive studies of individual differences in temperament and emotional reactions; and (4) studies of the physiology of the central nervous system in relation to instinctive and intellectual capacities as revealed in the above types of analysis of behavior. The resources of the Laboratories have been supplemented by the purchase of a group of spider monkeys from which it is hoped to develop a breeding colony of experimental animals.

Primary emphasis will be placed on the research use of monkeys and apes as approach to the solution of human problems and as basis for the development of new phases of human engineering.

ROBERT M. YERKES

CRANBROOK INSTITUTE OF SCIENCE EXHIBIT OF MICHIGAN PLANT LIFE

AGASSIZ's admonition, "Study Nature not Books," is being followed in the Cranbrook Institute of Science at Bloomfield Hills, near Detroit, Michigan. In its recently opened Hall of Plant Associations there are seven dioramas, showing typical examples of important Michigan plant communities.

Ranging over seven degrees of latitude and eight of longitude, Michigan comprises great diversity of terrain and vegetation types. Lower Michigan lies in the deciduous forest zone with two forest climaxes; oak-hickory and beech-maple. Upper Michigan is in the lake forest vegetation zone. Here evergreen trees are dominant and the coniferous forest is climax. As one progresses northward in the state pines become more plentiful, hickories drop out of the picture, oaks decrease in number and beaches finally disappear. These diverse climax types are direct responses to the great differences in climate, soil factors and physiography of the northern and southern parts of the state. They reflect the geologic history of Michigan and particularly the effect of the ice age upon her soil and countours.

In Cranbrook's Hall of Michigan Plant Associations typical examples of the three climax forests, conifer, oak-hickory, and beech-maple are authentically reproduced. With them are shown four other Michigan plant communities which are transitional and successional communities leading up to the three climaxes.

The rich deep coniferous forest near the tip of the Keweenaw Peninsula has been reproduced as it appears in late August. Beneath pines, balsam, spruce and cedar grow arbutus, starflower, pipsissewa and bunchberry with its clusters of bright red fruits. In dense shade only thick mats of dark green moss and tufts of reindeer lichen grow in the fragrant needle carpet. Such forests develop through long stages of growth and change. They may begin from such apparently remote origins as cobble beaches on the northern shores of Lake Huron or the sun washed dunes of Lake Michigan's eastern shore.

Typical of these cobble beaches is the south shore of Bios Blanc Island, in the Straits of Mackinac, as shown in the Cranbrook exhibits. Here is clearly evident the trend of succession from water's edge, through a flower strewn beach where fringed gentian, pink foxglove and green and white grass of parnassus abound to the wave-free high beach where the evergreen forest wall rises abruptly.

Sleeping Bear Dune, Leelanau County, the largest moving dune in Michigan, has been selected as best exemplifying the transition from loose shifting sand to capture by coniferous forest. A portion of this extensive dune is shown as it appears in August. Wind swept areas where plant life is reduced to sparse growth of dune grass; quiet places where dune thistle, wormwood, harebell, and puccoon gain footing; as well as twisted poplar trees, a fossil forest, and typical "blow-out" are shown. Here also is seen a partially held dune known as a "Gibraltar" and a completely captured and forested dune, the Great Bear, perched on a bluff many hundred feet above Lake Michigan.

SPRUCE–CEDAR BOG

PINK AND WHITE, YELLOW AND STEMLESS LADYSLIPPERS GROW IN AN ACID SPHAGNUM BOG WITH CRANBERRIES AND PITCHER PLANTS. BLACK SPRUCE, CEDAR AND TAMARACK TREES SHELTER THESE DELICATE PLANTS.

SAND DUNE

HERE, ON SLEEPING BEAR, MICHIGAN'S LARGEST MOVING SAND DUNE, WIND-BLOWN SAND CHERRY, WORMWOOD AND SAND-BINDING GRASSES INDICATE THE DIRECTION OF PREVAILING WINDS. A FOSSIL FOREST, BLOW-OUT AND PARTIALLY CAPTURED AREAS ARE ALSO SHOWN.

OAK–HICKORY FOREST

ON WELL DRAINED MORAINIC SOILS, FORESTS OF OAK AND HICKORY SHELTER DELICATE SPRING BLOOMING TRILLIUMS, VIOLETS, JACK-IN-THE-PULPIT AND MANY OTHER EARLY-APPEARING WILD FLOWERS WHICH FADE WITH THE INCREASE OF THE LEAFY CANOPY AND HIGHER TEMPERATURES.

Trending toward the two hardwood forest climaxes characteristic of lower Michigan are many transitional groupings of plants. Two are shown in the Hall of Michigan Plant Associations.

A spruce-cedar bog in the southern part of the state has been selected as outstanding. These bogs trace their origin to glacial times when blocks of ice, slow in melting, left depressions more or less filled with cold water. Boreal plants usually found in latitudes far to the north have become well established in these situations, but disappear when the bog silts in and the water table changes.

In the bog shown at Cranbrook moisture-retaining, moss-covered hummocks and dark lily-covered pools are sheltered by pyramidal black spruce, tamarack and cedar trees. Here in these difficultly penetrated bogs grow rare orchids like the yellow, pink and white and stemless lady's slippers. With them fragrant rose pogonia, cranberries, pitcher plants and wild white calla lily are found. Sheltering shrubs are chiefly blueberry, rosemary and poison sumach.

Frequently, as the water table changes dry meadow succeeds wet bog. Here in the absence of all shade, sun-loving wild carrot; chicory; Black-eyed Susan and bee balm grow in a dense matrix of timothy and blue grass. Such an open meadow in southern Michigan has been reproduced in Cranbrook's plant hall.

As shrubs and trees gain foothold, meadow plants disappear. If the terrain be well drained and of light textured soil, oak-hickory forest will succeed dry meadow. Such a forest as it appears in May with its profuse carpet of shade-loving delicate flowers is shown. Under sheltering oaks and hickories with wild cherry and shadbush bloom hepaticas, trilliums, blue violets, May apple, Jack-in-the-Pulpit and Dutchman's breeches.

Of distinct contrast to the flower strewn forest floor of typical oak-hickory forest is the clear open sweep of mature stands of beech and maple. In this woodland only a few herbs are seen. Ferns, beech drops and Indian pipe grow here. Occasional red-berried elder, Virginia creeper and trailing bedstraw augment

the scant growth. Beech and hard maple trees with a few butternuts and tulip trees form the forest canopy.

Cranbrook Institute of Science presents these seven reproductions of Michigan plant life for the pleasure, the inspiration and the education of the people. Here they may be seen not only by those familiar with their originals but by many never able to seek their counterparts in reality. For the teacher and the student they are a book of three-dimensional illustrations. For the casual visitor there is pleasure and stimulation to a better appreciation of our natural surroundings. For all, there is conservation of a high order and silent appeal for the preservation of some of our richest resources.

MARJORIE T. BINGHAM

DEVELOPMENT OF INTERACTIVE SOLAR PROMINENCES

PROMINENCES on the sun are roughly divided into five classes; Quiescent, Active, Sunspot, Eruptive, and Tornado. The ordinary active prominences are those from which streamers are pulled into centers of attraction located anywhere over the solar surface. In the sunspot, active type streamers are pulled into centers of attraction located within a sunspot area. So far as we know both these types of prominences may disappear principally in three ways: (1) by shredding, *i.e.*, they are torn apart and pulled into the sun in the form of streamers, (2) by a quasi-eruption which occurs when the shredding becomes very rapid, the whole prominence rises, moves over an arc and down into the center of attraction on the sun, and (3) by an eruption when, for some unknown reason, the prominence begins to rise, moves away from the sun, then disappears by fading out at an elevation which often amounts to several hundred thousand kilometers.

Occasionally the prominence will divide, a part becoming quasi-eruptive and a part eruptive. In any event streamers continue to rain down to centers of attraction upon the sun as the prominence rises. The characteristics of the movements of prominences point to electrical charges rather than light pressure as the motive force. Since the study of prominences without an eclipse began 73 years ago, 64 eruptive prominences have been found to follow this pattern of development.

A rare form of the active type is the interactive prominence in which two or more prominences are connected by streamers. Very little was known about this type. On August 7 and 8, 1942, one was photographed with the newly de-

FIG. 1. ERUPTIVE PROMINENCE OF OCTOBER 6, 1942
EXPOSURES AT INTERVALS OF 23 MIN. HEIGHT OF PROMINENCE IN THE LAST PICTURE 250,000 KM.

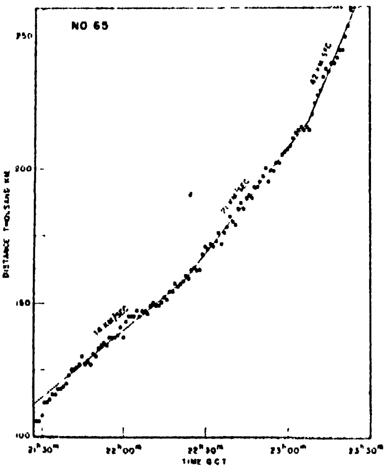


FIG. 2. TIME-DISTANCE DIAGRAM OF THE ERUPTIVE PROMINENCE OF OCTOBER 6, 1942. STRAIGHT LINES IN THE DIAGRAM SIGNIFY UNIFORM MOTION. VELOCITIES ARE INDICATED.

veloped monochromator which showed that the prominence gases in a pair of streamers were moving in opposite directions. This movement of gases from one prominence to another seems to require that electric charges of either sign may occur in a prominence. Why such a prominence does not collapse is a mystery, for the ionized calcium atoms, which always form part of the gaseous material, have the positive sign only. There is no difference in the forms of prominences photographed in ionized calcium or neutral hydrogen.

Of the development and distinction of interactive prominences very little is known. One which crossed the disk in July, 1941, was converted into a pair of ordinary active prominences when two centers of attraction developed beneath the connecting streamers and pulled them into the sun.

On October 6, 1942, an interactive prominence which appeared on the west limb of the sun developed into an eruptive prominence. When first seen it was a pair of comparatively small prominences consisting of one 35,000 kilometers high pouring fine streamers into another 14,000 kilometers high 60,000 kilometers south of it. By early afternoon the pair of prominences were fused into a single unit which had risen to more than 100,000 kilometers and photography was continued until it was lost in an overcast sky at 23^h 24^m G.C.T.

From the monochromator film on which exposures were recorded at 1-minute intervals we have selected the 6 exposures at 23-minute intervals shown in the accompanying photograph. In the first exposures the prominences are seen blended into a triangular form. This grows into a column which bends over and a streamer is pulled back upon the sun as the prominence rises.

This prominence moved along a trajectory which, extended backward to the sun, made an angle of 34° to the solar radius. The measures of the distance of the top of the prominence from the sun were made along this trajectory which was sensibly straight and the resulting time-distance diagram is shown in Fig. 2.

The straight lines shown in the photograph indicate that the velocity was constant, except when it increased rather abruptly at intervals. The slopes of the lines indicate velocities of 14, 21 and 42 kilometers per second. In other eruptive prominences which we have studied each velocity is usually a small hole multiple of that preceding. This case illustrates one of the variants in which an interpolative velocity appears although we can not tell whether it is the first or second velocity since they are both factors of the third.

From this brief account of the present state of our knowledge of interactive prominences it will be seen that evidence is accumulating which indicates that the active and interactive types have common characteristics.

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QUALITY OF THE FOOD SUPPLY AND THE NEED FOR ITS CONTROL

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ABNORMAL mental attitudes, unhealthiness and inefficiency are attributed in large part to malnutrition. Their prevention ranks in public health importance with prevention of disease.

Programs of public education in nutrition are handicapped by defects in the *quality* of many foods. When common foods lack the nutrients they ought to have, planning diets that are adequate in all particulars involves more discrimination in food selection than is to be expected of average persons. Regulation of the *nutritive quality* of foods is a responsibility which government must accept. This is basic to successful planning for the peace.

Provisions can be made sufficient to win "freedom from want for all men everywhere," but freedom from want of food cannot be won without attention to the *quality* of the food provided. Men starve with hidden hungers in the midst of plenty.

* * * * * *

A national handicap for times of peace, a calamity for times of war—thus were described the qualitative shortcomings of many American diets in some of the discussion at the National Nutrition Conference for Defense which was held in Washington, May, 1941. It now is widely recognized that the economic as well as the physical security of nations largely depends on the nutritional condition of their populations. The ability and even the desire of any people for cooperative endeavor or exertion rests to no small extent on the *nutritive quality* of the food available. The Germans learned this from their defeat in World War I. In consequence they early put to work the newer knowledge of nutrition, which accounts in part for their early accomplishments in this later war.

In the present war the scientific control of food which the English government established has resulted in an actual improvement of the nutritional condition of the British population. The gain has been accomplished in spite of the fact that food shortage in Great Britain has been much more serious than it was in World War I.[1] Hostile submarines have been more destructive, and when the Germans invaded Scandinavia, the low countries and France, they cut off a third or

[1] "Food Control in Great Britain, Studies and Reports, series B (Economic Conditions No. 35)." Montreal, International Labour Office, 1942.

more of normal food supplies to the British Isles.

The successful management of foods in Britain has been so convincing of the value of scientific guidance in policies affecting food that British leaders, conservative and liberal alike, expect their government, at the conclusion of the war, to continue present efforts directed at increasing efficiency of distribution, with subsidies, where subsidies are necessary, to insure that the most necessary foods, such as milk and fruit, reach those too poor to buy them.[1] They also expect continued efforts to influence production of better foods, and to fortify with vitamins and minerals where this is necessary to improve a food which forms a large part of the diets of the population. Reinforcement of oleomargarine with vitamins A and D is an example. This already has been made obligatory. The milling of flour in such a way that more vitamins are retained or the alternative addition of vitamins removed in milling also is obligatory. These are examples of recognition by the British government of a need for standardizing foods for *quality*.

In the United States public interest in food values and in food supplies is developing rapidly. At the National Nutrition Conference[2] already mentioned many disagreeable facts were brought into the open. Production of food was ample but distribution and preparation for consumption were at fault so that in the midst of plenty many persons failed to receive the nutrients they ought to have.

The recommendations of the conference were given prompt attention. A national nutrition program was undertaken, with direction provided by the Office of Defense Health and Welfare Services. Committees on nutrition have been set up at state and local levels. Information about food and diet is now distributed by many organizations, national and local. Particular attention is directed to improving the diets of workers in defense plants.[3]

Through the stamp plan and by other mechanisms of the Agricultural Marketing Administration (now absorbed by the Food Distribution Administration) nutritionally better food has been made available to some low income groups at prices which enable them to buy it. These measures have been in effect for several years, but on March 1, 1943, the stamp plan was suspended. However, some direct distribution of commodities purchased by the Administration to public assistance families will continue. School lunches and distribution of inexpensive milk, although under way for several years, are now receiving more attention. America owes much of what improvements have been made in the quality of its bread and flour to patriotic volunteer endeavors of its baking and milling industries. The rapidly growing use of enriched flour and bread and of fortified oleomargarine is gratifying. However, even the battle for better bread and butter will not be won until adequate standards for enriched flour and fortified oleomargarine apply to all bread and flour and to butter as well as to butter substitutes.

In this country, as in Britain, the belief is entertained that the ground already gained on these food fronts has set nutritional frontiers, and that these frontiers, with the coming of the peace, should be advanced not only in our coun-

[2] "Proceedings of the National Nutrition Conference for Defense," May 26–28, 1941. Federal Security Agency, Office of the Director of Defense Health and Welfare Services, United States Government Printing Office, Washington, D. C., 1942.

[3] The British have shown that industrial production can be speeded up by providing well planned extra meals to workers in defense plants, and the Imperial Government Institute for Nutrition in Tokyo has operated kitchens for many years in various parts of Japan where diets of high value are scientifically prepared and served at minimal cost to factory workers.

tries but throughout the world. The questions now to be considered are how to hold the ground that has been won, and how to push ahead toward the goal of providing food that will more assuredly supply the nutrients required for vigorous minds and bodies.

Education in Nutrition

It is not to be supposed that when the war is won public interest in nutrition will continue as at present. In ordinary times people eat what pleases them with little thought of what food does to them. For a hundred years physicians have inveighed against denatured foods, and for more than twenty years nutritionists have urged the greater use of what are called protective foods—milk, fruit, and leafy green and yellow vegetables. Results of all this education before the war were disappointing, and even with the impetus engendered by the war and appeals to patriotic motives, such education is not at present reaching those persons who need it most—the underprivileged who neither read nor listen.

I want it clearly understood that I am not disparaging the importance of nutrition teaching—far from it! Much has been accomplished by this teaching, and the effect of it is sure to influence post war thinking. Also, if any progress is to be made in securing foods of better quality, public demand for better quality must be created. This requires education. My point is only that nutrition teaching cannot be depended on to do the job alone. Appeals to health, as I have said, are ineffective. Add to this the competition from a powerful array of appeals to taste by purveyors of foods of doubtful value and the problem grows in magnitude. Food industries by their advertising reach people by the thousands for every man or woman instructed by the teacher of nutrition. Education at its best is a slow and painful process, and timely execution of the recommendations of the National Nutrition Conference will require something more than education.

Public Health Activities and Application to Nutrition

Today's problem of improving diets is much like that which confronted those who wanted better sanitation some fifty years ago. The public educator in sanitation had met with only fair success by 1890 and the regulatory procedure, which later was dramatically effective, had not as yet been widely undertaken.

The origin of the English Code of Sanitary Legislation is attributed by Garrison to a popular reaction which started, in the first half of the nineteenth century, to the let-well-enough-alone doctrines of Adam Smith, James Mill and Malthus. They and other professors of the so-called dismal science held that poverty and distress were unavoidable, since increase of population must occur at a more rapid rate than increase in the means of subsistence. The fallacy of that conclusion was revealed in the writings of Victor Hugo and Charles Dickens. Production of goods was seen to depend on the industry and ability of the people who produce them, and the ability to produce to lie in the health and vigor of the population. At the beginning of this interest in public health much emphasis was placed on food. The early English writers on hygiene attributed the sickliness of the people of the slums of London and other English factory towns to insufficiency of food. On the continent of Europe, a century before, Johann Frank had demanded free meals for children and other measures for bettering the nutrition of the poor. This interest in food later waned, mainly because the discoveries of Pasteur, Koch and their successors showed that many diseases were bacterial in origin. Attention to the food supply came to be centered almost wholly on questions of food contamination.

At the turn of the century it was commonly believed that lack of sanitation, personal or environmental, was responsible for almost all disease and that cleanliness was the answer to the major hygienic problems. However, teaching that water should be boiled before drinking, and that the private privy should be screened, proved ineffective in preventing epidemics of typhoid fever. Teaching that milk carried germs and therefore should be boiled before consumption was also ineffective. Boiling changed the taste of milk and people were not willing to accept the change in taste. Jacoby[4] advocated boiling milk in 1873. He wrote in 1895 "that if raw milk could always be . . . fresh and untainted it would require no boiling, but . . . scarlet fever and diphtheria are met in the homes, about the clothing and on the hands of dairy men and women and typhoid stools are mixed with the water which is used for washing the utensils."

It finally became obvious to men of vision that something more than education was required. Charles North[4] had this to say of milk: "If milk infections were so serious a menace . . . and if the prevention of such infections was a public health measure of such importance, then pasteurization of milk in the homes by the consumers themselves was a remedy wholly inadequate to secure the results desired. Only a small fraction of the population could be expected to use this process, and even when used it must necessarily be accompanied by intermittance, irregularity and unreliability." A few years later in very many of the towns and cities of the United States and other countries pasteurization in the dairy was required by regulation, the safety of water supplies had been assured and sanitary systems for disposal of sewage had been adopted.

A dramatic fall in the death rate has followed the introduction of these and other similar regulations. Longevity in the United States has almost doubled since 1882. The services of public health have every reason to be proud of this achievement, although it also must be recognized that extending length of life does not alone imply creating a more healthy life. "If the reasoning 'low death rate therefore good health' is sound, then if in an institution filled with incurables there is no death, the death rate becomes nil and consequently the institution the healthiest in England, though there is not a single healthy person in it."[5] In point of fact, good health depends as much on diet as it does on cleanliness. "Uncleanliness and faulty food are partners in disease production—the one the coadjutor of the other."[5] "To add life to years as well as years to life" must be the aim.

The comment of Charles North relative to the need for public control of sanitation applies as well to the present problem of improving the quality of diets. If prevention of the ill effects of poor diets is as important a public health measure as is believed, how can it longer be considered reasonable to permit the marketing of foods which fail to carry the nutrients which people ought to find in them? Surrounded as consumers are with inferior foods, the fraction of the population which can be educated to exercise the discrimination necessary to select a good diet must be very small. On the other hand, if the nutritive quality of the more important foods could be assured by public regulation, the problem would be nearly solved. People then would find themselves in a nutritional environment in which it would be difficult to go wrong, instead of, as now, in a situation in which it is difficult to go right.

[4] Ravenel, M. P. "A Half Century of Public Health." New York, American Public Health Association, 1921, pp. 76, 82, 271–273.

[5] McCarrison, Robert. "Cantor Lectures I, II, III. Nutrition and National Health." *Roy. Soc. Arts. J.* 84: 1047–1066 (Aug. 28); 1067–1083 (Sept. 4); 1087–1107 (Sept. 11), 1936.

IMPERFECTIONS OF THE FOOD SUPPLY

Experiments performed under my direction[6] confirm the views of many others that the present food supply is most unsatisfactory. In these experiments measured foods, of which the composition had been determined by analysis, were fed to volunteers. The amounts of each food given were such as to make the diet simulate the hypothetical average American diet of 1939. In other words, the calories provided by white flour (unenriched) represented 25 or 30 per cent of the total calories consumed, and calories from other vitamin poor foods, such as sugar, polished rice, cornstarch, cornmeal and the like, provided another 15 or 20 per cent of all the calories. This diet contained a fair portion of meat, butter, a small salad of fresh vegetables, as well as processed fruits and vegetables, and yet despite the presence of these "protective foods" the subjects who lived on the regimen for several months developed serious disabilities. These could be prevented by adding a pint of milk and by selecting vegetables and fruits which contained more vitamins, or if the bread used was enriched bread or whole wheat. The point is that a diet containing as much unenriched white bread and sugar as people commonly consumed in 1939 can only be made adequate by a very wise selection of the balance of its foods. In point of fact, with consumption of flour and sugar at present levels, even if the flour is of the enriched or whole wheat flour variety, the nutritional situation in this country is one in which the necessity for discriminating diet planning is greater than can be viewed with equanimity.

The major current problems of nutrition are created by commercial processing of foods. Flour and sugar are the worst offenders in the Occidental countries because of the magnitude of their contribution to the diet. The bread grains represent a most important source of certain vitamins, but in converting wheat into white flour from 86 to 90 per cent of one of these vitamins (vitamin B_1, thiamine) is lost and from 60 to 80 per cent of another vitamin (niacin) is removed. Minerals are also lost; chief of them is iron. The answer to this white bread problem is either the preservation or the restoration of these nutrients.

Sugar presents a somewhat different problem. Sugar is the purest food known —innocent almost of any vitamin content—and its consumption has replaced much of the consumption of flour of earlier times. In effect, sugar constitutes an adulteration of the diet because the flour it replaced was not the vitamin poor white flour of the steel roller milling of the present, but the coarse gray vitamin rich product of the stone milling of the past. What to do with sugar is a puzzle. Some restriction of consumption appears to be the only answer.[7]

Rice contributes as much as 80 or 90 per cent of the calories of the diets of some populations of the Orient. It also is used extensively by some portions of the American population, notably in the Philippine Islands, in Puerto Rico, and in certain communities of the lower part of the Mississippi valley. Extensive milling, so-called polishing, removes the vitamins from rice and this processing is responsible for untold human suffering. It is high time for action in this matter. It is nearly fifty years since proof was brought by Christian Eijkman that commercial processing of rice was the cause of the "epidemic" beriberi of the Orient. In some parts of the world beriberi is

[6] Williams, R. D., Mason, H. L., Power, M. H., and Wilder, R. M. "Induced Thiamine (vitamin B_1) Deficiency in Man: Relation of Depletion of Thiamine to Development of Biochemical Defect and of Polyneuropathy." *Arch. Int. Med.* 71: 38–53 (Jan.) 1943.

[7] Council on Foods and Nutrition. "Some Nutritional Aspects of Sugar, Candy and Sweetened Carbonated Beverages." *J. A. M. A.* 120: 763–765 (Nov. 7) 1942.

responsible for more than a fourth of all diseases. A standard of identity and quality for rice which included the provision that a certain percentage of the outer skin should be retained would solve this problem.[8]

Methods of canning as now provided by the industry are excellent for the most part, but in some canneries control is lacking and thus some foods are grossly injured in their canning. An example is tomato juice which is much in demand, not only because of its pleasing taste but also because the public or a part of it has learned to recognize the tomato as a good source of the anti-scurvy vitamin, ascorbic acid (vitamin C). Yet among thirty samples of tomato juice tested for their content of this vitamin at the Connecticut Agricultural Experimental Station, only three contained an amount equal to what may be regarded as average for fresh tomatoes. Six samples contained 15 milligrams per 100 grams or less, representing only 60 per cent or less of what should be expected in tomatoes.[9] At the same laboratory analyses were made of forty-nine samples of orange drinks. The results showed that few of these drinks contained significant amounts of vitamin C and that twenty-nine had a vitamin C potency of less than two per cent of fresh orange juice. This is a matter of great importance because orange drinks are associated in the minds of the consumer with a high content of vitamins, and the teachers of nutrition are teaching that it is difficult to prevent scurvy without including citrus fruits in the diet.

Numerous other examples can be cited. The Bureau of Home Economics of the United States Department of Agriculture prepared a compilation of vitamin values of foods as recorded in the scientific journals published up to December, 1940.[10] The lengthy tables provide the data, not only for fresh or uncooked foods, but also for foods after storing, cooking and commercial processing. The review reveals conclusively the need for controlling the nutritive quality of processed foods. For example, the content of vitamin A of different samples of butter ranged from 27,000 to as little as 2,800 international units to the pound. Green peas, by rights, ought to be a product on which dependence can be placed to compensate for the small amounts of thiamine contained in other vegetables. A reasonable expectation for thiamine in peas is 390 micrograms per 100 grams; which represents about a third of a day's requirement of this vitamin. Some samples of processed peas contained as much as this or more; others contained half as much or even less. Several samples of canned salmon contained 500 international units or more of vitamin A per 100 grams; but other samples contained less than one-tenth of this amount. Methods of processing are responsible for many of these differences. Meats suffer greatly in their content of thiamine when subjected to the high temperatures developed in autoclaving. A sample of canned pork, for instance, which assayed when raw 1800 micrograms per 100 grams contained, after preheating at fifteen pounds of pressure, only one-eighth of this amount. Pork is a meat

[8] Vedder, E. B. "Beriberi." New York, William Wood & Co., 1913.

[9] Dr. L. A. Maynard, Director of the Cornell Nutrition School, has stated that studies with tomato products caused surprise at the large losses in canning, as carried out by some leading producers. "It is interesting," he further stated, "that with the recognition of the need for 'protective foods' measures were taken to increase yields and 'market quality'; vegetables and fruits were bred for drought resistance, cold and disease resistance, etc., but in all of this development little attention has been paid to the real reason why these foods are needed in the diet—their content of nutrients which make them protective."

[10] Booher, Lela E., Hartzler, Eva R. and Hewston, Elizabeth M. "A Compilation of the Vitamin Values of Foods in Relation to Processing and Other Variants." (Circular 638) United States Department of Agriculture, May, 1942.

unusually rich in thiamine and its occasional consumption does much to prevent the development of deficiency from the scarcity of thiamine in the average diet.

A problem even more serious than that created by canning is presented by the processing of foods by dehydration. This method for preserving perishable commodities promises to become very popular. Costs of transportation can be minimized by dehydration to the advantage of the consumer. However, unless the dehydration of the food is done with care, heat-sensitive constituents are lost. This industry, unfortunately, is new and not well organized. Many newcomers in the industry lack knowledge of the difficulties involved and possess inadequate facilities for controlling their procedure. It also appears that losses of vitamins C and A result from long storage of dehydrated vegetables. Therefore the labels of such products should be dated. They should also carry a statement of vitamins C and A values on rehydration after storage for some months.

Existing Food Control in the United States

Consumer interest in food has mainly been directed in the past at protecting pocketbooks and preventing poisoning. The issues have been package size, package labels, physical quality[11] and purity. The laws were known as pure food laws. Filth and decomposition were vigorously and effectively combated. However, it should be pointed out that many foods are marketed under the supposition that they are nourishing when they are not, and therefore that exploitation is not prevented by this degree of food control; also to be noted is the fact that effort directed at increasing purity has resulted in many instances in injury to the *nutritive quality* of the foods involved.

Federal legislation for control of food has succeeded in correcting many of the evil or careless practices of the past. Spoilage by insects or bacteria, contamination with metals, such as lead, or with poisonous preservatives have largely been eliminated. A processor may not dilute his product by the addition of adulterants. This prohibition holds even if the adulterant used is harmless. The reason that harmless adulterants are objected to is that their addition to a food dilutes the nutritive value of the product. However, this reasoning is not carried through. In the present interpretation of the Federal law it is held that there is no provision in the law to prevent a processor from damaging his product by withdrawing or destroying its content of minerals or vitamins.

The standards for foods which have been established under the Food, Drug and Cosmetic Act[12] are standards of identity and are based mainly on physical properties. According to earlier Regulatory Announcements, they "are not to be confused with standards of quality or grade; they are framed so as to exclude circumstances not mentioned in the definition and in each instance imply that the product is clean and sound."[13] This is the language of the

[11] Among the recommendations of the Section on Economic Policy, Section II, of the National Nutrition Conference for Defense (Proceedings, p. 96) is one which would favor "the extension of grade labeling of foods and the revision of Federal grades of fresh fruits and vegetables to reflect differentials in nutritive value." Another (p. 97) would favor "the provision of more information in advertising to facilitate the identification and comparison of the quality of food and size of container." There is some recognition in these recommendations of the importance of control of quality—but emphasis on nutrient quality still is lacking at this late date.

[12] Federal Food, Drug and Cosmetic Act and General Regulations for its Enforcement. United States Department of Agriculture, Service and Regulatory Announcements, Food and Drug Administration, August, 1939.

[13] Definitions and Standards for Food Products for Use in Enforcing the Food and Drugs Act. United States Department of Agriculture, Service and Regulatory Announcements, Food and Drug Administration, Revision 5, November, 1936.

regulations. Responsibility for the *nutritive quality* of foods is disclaimed, and yet in some cases definitions of identity do make reference indirectly to nutritive constituents. For example, the definition for oatmeal[13] prescribes that the amount of nitrogen contained shall not be less than 2.24 per cent. This specification relates to a content of protein and prompts the question why, if a minimal content of one nutrient (protein) can be required, it might not also be possible, under existing legislation, to require minimal contents of other nutrients, such as vitamins and minerals.

Methods are now available for testing foods for content of nearly all their minerals and many of their vitamins. Were nutrient standards to be established they could be limited to nutrients for which methods of analysis are satisfactory. The nutrients most frequently lost from foods are those which are sensitive to heat or light. Among them are vitamin A, thiamine, riboflavin and ascorbic acid. Each of these can be easily identified, and if tests for them are made and the losses found are small, it is reasonable to suppose that the food examined has not suffered loss of other vitamins. For example, in the cited definition of oatmeal, if a minimal content of only thiamine could be required the *nutritive quality* of the product as a whole would be reasonably assured, whereas for lack of such control certain brands of oatmeal on the market, as well as many other breakfast foods, have been subjected in their processing to destructive temperatures.

Individuals in the Food and Drug Administration and the Federal Security Agency have not been unmindful of the nutritional element in food as a factor which could be employed in the formulation of standards of quality. However, up to now the Food, Drug and Cosmetic Act of 1939 has been invoked to control the nutritive quality of a food only when claims have been made for vitamin, mineral or other dietary constituents. In case a claim is made for such constituents the label on the food must bear certain information concerning these constituents. For example, enriched white flour, as now defined by regulation, must contain certain vitamins and minerals in prescribed proportions, and the label must tell to what degree the amount of each of these vitamins in a given portion of such flour contributes to minimal daily requirements. This is very good, but there is nothing in the law as now interpreted to make it possible by regulation to prevent the sale of white flour which is not enriched. Likewise, if the manufacturer of a tomato juice makes a claim for the vitamin C in his product, the amount claimed must be there and he must indicate on his label to what degree the amount in a given portion of the product will contribute to the minimal day's requirement of vitamin C. However, if no claim is made the product may contain no vitamin C at all and yet be marketed without penalty as tomato juice.[14] At the present time, owing to the absence as yet of controlling court decisions relating to the scope of the administrator's authority in the issuance of regulations formulating standards of identity and quality for food products, the Food and Drug Administration is faced with serious legal problems. The courts are in a position either to strengthen or to weaken the present act, depending on whether they will view with understanding the significance to the welfare of the nation of this problem of nutrition.

The fact that Federal regulation for

[14] This is an extreme assumption. Reading it, Dr. E. M. Nelson of the Food and Drug Administration, in a letter to the author, made the comment that he was not sure that such a product could be marketed without penalty. No cases of this kind had come to his attention, but he believed that vitamin C is such a well-recognized constituent of tomato juice that a product sold under the name "tomato juice" and containing no vitamin C would not conform in identity with the product ordinarily sold under that name.

control of foods can apply only to products in interstate commerce presents some handicaps to effective action in this country for control of food supplies. However, most of the food that requires regulation is shipped across state lines and thus comes under Federal regulation. Also, Federal action in setting standards of identity serves to establish patterns for legislation by the states. An example is the procedure which was followed by the Food and Drug Administration in controlling enriched flour. As was stated before, this involved little more than the promulgation of a definition. It restricted fortification of flour with vitamins and minerals to the standards established for enriched flour, but it in no way prevented the marketing of plain or unenriched white flour. However, soon after the promulgation of this definition the state of South Carolina passed a law requiring that all white flour sold in the state must meet the Federal standard for enriched flour. Louisiana now has a similar law and other states are expected to follow. South Carolina and Louisiana also require that oleomargarine be fortified with vitamin A, again adhering to a standard of identity established at the Federal level.

It is not for me, a physician and little acquainted with law or administration, to prescribe the means for accomplishing what so obviously is necessary to improve the *quality* of the food supply. Existing legislation in the United States, if liberally interpreted by the courts, may permit the establishment of standards of *nutritive quality* by regulation. Section 401 of the Food, Drug and Cosmetic Act provides: "that whenever in the judgment of the Secretary (Administrator) such action will promote honesty and fair dealing in the interest of the consumer he shall promulgate regulations . . . establishing for a food . . . a reasonable standard of identity, (and) a reasonable *standard of quality*."[15] In my opinion the court could justly interpret the words "standard of quality" as implying a standard of *nutritive quality*. However, among the foods for which standards of nutritive quality are most needed, as I have pointed out, are dried fruits, dried vegetables and butter, whereas the language of Section 401 of the Food, Drug and Cosmetic Act goes on to state, "provided that *no*[15] definition and standard of identity and *no* standard of quality shall be established for fresh or dried fruits, fresh or dried vegetables or butter. . . ." In the light of this restrictive language some revision of the act seems necessary.

Decisions as to what foods are most in need of improving and how their improvement is to be effected should obviously be based on advice obtained from experts in the science of nutrition. The Federal Government now has at its disposal, available at all times for consultation, the Food and Nutrition Board of the National Research Council. This Board is composed of physicians and scientists selected from among authorities in the science of nutrition. The membership, for the most part, comes from the leading universities of the country, and policies having to do with the nutritional aspects of food could be wisely and impartially guided by such a body. Precedent for the suggestion can be found in another section (Chapter V) of the Food, Drug and Cosmetic Act.[12] Although, as I have pointed out, this act does little to prevent the marketing of foods that fail to measure up to any standards of nutrient quality, it deems a drug to be *adulterated*[15] (Section 501b) if "its strength differs from or its quality . . . falls below" certain standards. Furthermore, the standards recognized are those established by authorized scientific bodies and the responsibility of these bodies extends to designating the tests or methods of assay for determining whether the strength, quality or purity of drugs meets these standards.

[15] Italics mine.

Foods in International Trade and Their Control

There is much thought given now, in this the fourth year of the war, to setting up a world authority which, when peace comes, can assume the guidance of international relations. There is wide agreement that the establishment of this authority should include an agency for reorienting agriculture and that subsidiary to the latter, but also related to whatever body is organized to deal with health, an international food administration will be required. The objective of these proposals is to implement that provision of the Atlantic Charter which calls for freedom from want "for all men everywhere," as the President said, "in our own day and generation." It is held that food is the most essential of all human needs, and that food adequate for health for all is a realizable ideal. Accomplishment of this ideal is expected to require a sustained campaign. An early responsibility of the authority that has to deal with the international aspects of this activity should be to set up standards of *nutritive quality* for the major food supplies which move in international exchange. If this is done, and if the means for enforcing adherence to such standards are provided, the food quality problem of every nation associated with the world authority would inevitably be affected. Foods which met whatever nutrient standards were imposed would be designated and presumably could be labeled "Authority Approved" so that everyone would know that such foods were better foods and hence desirable. In consequence manufacturers, processors and distributors of food in every nation would strive to have their products meet these standards. The competitive situation would automatically accomplish such conformance and probably most of the nations would adapt their standards for foods to those which were set up by the world authority.

Even a small advance in this direction would prove immensely beneficial. If

TABLE 1

Analysis of English Diets for Adult Men*

	Calories	Protein, gm.	Calcium, gm.	Iron, mg.	Vitamin A, international units	Ascorbic acid, mg.	Thiamine, mg.
Middle class diet today	3,310	110	0.6	12.3	5,170	70	1.2
Poverty diet today	3,000	78	0.3	8.4	520	15	0.66†
Middle (artisan) class diet, 1826	2,130	125	0.2	45	1,220	0	1.77
Navy ration, 1811	2,750	110	0.7	18	2,600	0	3.15
St. Bartholomew's Hospital, 1686	2,600	80	1.9	12	5,100	10	1.89
Meat-eating classes, XV Century	3,650	250	1.3	50	7,000	?	3.30
Peasant diet, XV Century	3,300	140	1.2	21	1,700	10–20	4.20
Recommended by Food and Nutrition Board‡	3,000	70	0.8	12	5,000	75	1.8

* From J. C. Drumond's "The Englishman's Food," London, J. Cape, 1940.

† A diet containing as little thiamine as this (0.22 mg. per 1,000 calories) provokes symptoms of severe athiaminosis.

‡ For moderate activity.

flour and rice alone could be controlled much good would come of it. One of the outstanding faults in the nutritional situation of Western Europe and America, as I have said, is related to the use of over-milled white flour. Comparison of diets of working class Englishmen and Americans in recent years with diets of

TABLE 2

LOW INCOME AMERICAN DIETS OF 1926 AND 1851 (FOR ADULT MEN)

	"Working mens" diet of 1926,* gm.	Low income diet of 1851†
Bread and cereals (flour in 1851 diet)	309	336
Sugar and sweets (sugar in 1851 diet)	61.5	55
Fats (butter in 1851 diet)	53	27
Lean meat (meat in 1851 diet)	225	192
Milk	278	50
Potatoes	210	400
Other vegetables and fruits	35.6	
Calories	2740	2306
Protein, gm.	92	92
Calcium, gm.	0.61	0.26
Iron, mg.	0.013	0.024
Vitamin A, international units	1774	1224
Ascorbic acid, mg.	62.5	45
Thiamine, mg	1.4‡	2.53‡

* Calculated from data in Appendix O, R. O. Cummings: The American and his food. Ed. 2, Chicago, University of Chicago Press, 1941.

† Calculated from a fifth the values given in Weekly Food Budget for a Family of Five, Philadelphia, 1941, Appendix F, R. O. Cummings. The bread-winner of the family probably received 2,700 calories.

‡ No allowance made for loss of thiamine in handling and cooking foods.

the past (Tables 1 and 2) reveal that the later diets provide more vitamin A and vitamin C but much less thiamine. The change in the supply of thiamine is radical. The greater use of greens and fruits in recent times accounts for better provision of the vitamins A and C. The substitution, about 1870, of roller-milled white flour for the coarse grayish flour of the middle nineteenth century, together with the greatly increased use of sugar, explains the smaller provision of thiamine. The same type of problem, but one that is more serious, was created for the Orient by commercial milling of rice. The so-called polishing of this staple removes the major source of thiamine from many Oriental diets.

The consequence of diminishing the supply of thiamine below a certain level —and many diets in England, America and the Orient provide a supply which falls below that level—is to provoke in the consumer a change in attitude from one of reasonableness to one of apathy or even to one of defiance. The scientific proof of this already has been published, and I submit that correction of this effect of thiamine restriction is of even more importance to successful planning for the peace than correction of all other aspects of the ill health caused by malnutrition. Cooperation is not to be expected from populations who are poorly supplied with thiamine. Probably lack of other nutrients is attended with a similar effect. It clearly follows, therefore, that regulation of the *nutritive quality* of foods is basic to successful planning for the peace.

CONCLUSION

I have limited this discussion to consideration of processed foods for the reason that the faults in them could be immediately corrected. However, other foods can also be improved in time. The so-called natural foods are by no means always what they ought to be. The soil is poor in certain regions and the products of such soil fail to contain some nutrients that ought to be contained in them. This at present is a major topic of investigation of the Agricultural Research Administration. The chemists

will in time be able to correct such abnormalities of the soil. The aim of agriculture until now has been at maximal yields per acre or at size and appearance of the product. The aim in the future should be set at high nutritional values. Methods and time of harvesting affect the vitamin contents of natural foods as do methods of storage. All these aspects of the problem of nutrition demand consideration by national and international authorities, but first things should come first and of first importance, in my opinion, is control of those foods, among them rice, the bread grains and their products, which contribute more importantly than any other foods to the total calories of the diets of the world.

Whatever the means which are adopted in this and other countries or by international procedure to improve the more defective foods, corrective action is a responsibility which governments must accept. The scientific groundwork for procedure to improve nutrition has lagged for many years behind the sciences which underlie administration of public sanitation. However, the science of nutrition is now full grown and the application of this science is just as urgent as prevention of disease by sanitation. The real wealth of nations issues from the vigor of the people who inhabit them. Energy and effectiveness depend primarily on food.

What the man of tomorrow is to have to eat will determine the kind of world that he will build. Thus the *quality* of common foods assumes today immense importance. This problem must receive attention in present planning for the peace.

ASTRONOMY IN GERMANY

The American Astronomical Society's Committee on the Continued Distribution of Astronomical Literature has just received a packet of various German astronomical journals and publications from seven German observatories, issued in 1939–41 and the first half of 1942. The stack, fully eight inches deep, is truly impressive, not only in bulk but in its evidence for continued serious research. Practically every branch of astronomy is represented, from historic research on Mayan astronomy, observations of asteroids, meteors, and variable stars, to highly technical work in celestial mechanics, various astrophysical problems, stellar statistics, and so on. Solar research, studies of Cepheid variables and of the zodiacal light are especially prominent.

The annual reports of directors of observatories give clues as to the effect of the war on the astronomers themselves. As in the case of our own observatories, the Germans have had to sacrifice some of their promising younger men, a few of whom have, indeed, been reported killed in action. A number of other deaths, especially among the older men, are likewise reported. A remarkable percentage of the smaller institutions seem to have suffered changes in directorship, reflecting the restlessness of the times. Among the authors of the papers, we note many unfamiliar or new names. On the whole, we feel far more impressed by an apparent undying interest in astronomy than by a fatalistic resignation to complete militarism among German astronomers. There is even evidence that some who are occupied in war activities find time for volunteer work at their observatories.

Numerous issues give abstracts of astronomical papers published in Italy; one, a list of those published in Japan. Pleasing, however, was the discovery that the numbers of the *Beobachtungs Zirkulär* published in 1942 give the indices of our American *Astrophysical Journal* and *Astronomical Journal*, and of the British *Monthly Notices* and *Observatory*. This indicates the efficaciousness in alien territory of the efforts of the Committee.

We also note the election, since the war began, of a Parisian and a Chinese to membership in the Astronomische Gesellschaft; and that an asteroid, discovered by a German, was named in honor of a Frenchman.

These publications are entirely devoted to astronomy. Their only reference to the war is in the personnel notes in the directors' reports. They serve no propaganda purposes. At almost every meeting of the International Astronomical Union, it has been commented that there are no national barriers among astronomers. We experience the same feeling on reading this mass of German astronomical literature. May our common understanding in this science eventually be extended to life in general.—*Dorrit Hoffleit, in "Sky and Telescope," February, 1943.*

PREFERENTIAL DRAFT TREATMENT FOR YOUNG MARRIED MEN

By Dr. CONSTANTINE PANUNZIO
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In former wars nations generally considered only the emergency of the moment and drew upon all men of military age regardless of marital status and without considering the effect on future manpower. In general, this haphazard practice is still being followed. However, the experience of the last war plus recent studies of population furnishes evidence which indicates that calling men of certain ages may produce very serious results in terms of future military power.

The outcome of diverse policies may perhaps be best illustrated by recalling what happened during the First World War in France and England. France, in response to the urgency of the moment, recruited from all the men of military age, regardless of their marital status or the reproduction-age to which they belonged. The result was that France had 1,040,000 fewer births during 1915–19 than it would have had if it had not been at war. This, of course, had no apparent result at the time. But twenty years later the loss did have a profound effect. When in 1940 France called its men to arms, it found itself with approximately 700,000 fewer men, twenty to twenty-five years of age. Germany also had fewer births—about 2,900,000—as a result of the First World War, but Germany was able to make up the loss by its larger and rapidly-growing population, whereas France, with a smaller and stationary population was unable to do so. At least one scholar foresaw the potential danger of that difference. In a remarkable statement, penned in 1918, Savorgnan, an Italian student of population, said that it would be between 1935 and 1940 that "the shadow of that loss in births" would hang most heavily over France. What that loss did actually mean to France in the crucial hour of 1940 no one can measure. There is documentary proof, however, that German officials were well aware of the fact and they seem to have timed their attack to coincide with the very moment when France was weakest in manpower.

England, on the other hand, employed a far-seeing policy. Utilizing the knowledge available at the time as to the high proportion of children which the younger segments produce, England adopted a recruitment method which made possible the maintenance of a relatively high birth rate during the war period. Briefly stated, England's policy generally encouraged child-bearing: (1) it deferred married men until the end of 1916, (2) it provided family allowances for men who married after enlistment, (3) it granted generous allowances to the wives of enlisted men and for each child, and (4) later, it made similar provisions for drafted married men. Largely as a result of this recruitment policy, the United Kingdom was able to sustain its birth rate to a remarkable degree. Consequently, while France lost 1,040,000 births during the War, the United Kingdom, with a population greater by more than four million persons, had only 650,000 fewer live births than it might have had. Moreover, with a faster-growing population, England was able to repair the loss while France was not. Inasmuch as these differences bore results in terms of effective manpower twenty years later, or between 1935 and 1940, they gave England a greater manpower than it would have had if it had not followed that policy. And this extra strength may have been a decisive factor

in the resistance England was able to give Germany in 1940.

In order to realize the effect on future manpower when youthful married men are called to arms, it is necessary to bear in mind that in the United States the younger mothers give birth to a very large proportion of all children. In 1930 (the 1940 Census data are not yet available), mothers between the ages of twenty and thirty-four, inclusive, produced 72.6 per cent. of all live births. Moreover, within this group, it was the mothers between twenty and twenty-four who contributed the largest proportion. Since males on the average are three years older than females at first marriage, about three-quarters of all births occur roughly when the fathers are between twenty-three and thirty-seven, and within that group the greatest contribution is made by men between twenty-three and twenty-seven years of age. Or if we take into consideration a more significant fact, age of conception, the men would be twenty-two to thirty-six years old for the entire group and twenty-two to twenty-six for the more productive element.

In terms of future manpower, then, it is a very serious matter to call any considerable number of the married men between twenty-two and thirty-six, and even more so to call married men between the ages twenty-two and twenty-six. It is true that some of these men are urgently needed; still, the future strength of the nation makes it imperative to give some consideration to deferring them, whenever possible. It is a striking fact that Germany, though facing a far more difficult situation, is doing everything in its power to maintain or even raise the birth rate in the midst of war.

For the United States the problem is even more acute because our military forces are stationed far away, which, in most cases, renders it impossible for men to return home even though on leave. Because of this fact, the withdrawal of men of the specified ages cuts down births at a greater rate and creates more of a loss in future manpower than in countries close to the scenes of operations.

Likewise, the withdrawal from home of married women between the ages of twenty and thirty-two, even for essential war industry and service, is a matter of great concern, since such a procedure inevitably decreases the reproduction activity of these women.

Our situation is even more serious because the population of this country is fast becoming stationary, while the populations of some rival countries are still growing rapidly. Our present rate of increase is barely enough for replacement, while that of Japan, for example, is considerably above it. By 1970, Japan's total population is expected to increase by about thirty millions, while that of the United States will add eighteen millions. And since the age structure of the two nations is markedly different, Japan will have an appreciably greater proportionate increase in manpower than will the United States. Any loss in births at present on the part of the United States will, therefore, be far more serious than that which Japan can experience. In view of these facts, the United States and Japan will face a manpower situation somewhat similar to that which France and Germany faced in 1940. This statement is intended to create alarm, but even more to stress the full import of the situation. Even if we should deal Japan a knock-out blow now, in the next generation, we may be obliged to confront a nation with an even greater manpower than it now possesses.

As one authoritative voice has expressed it, "With a large element of our able-bodied men in the armed services—and the consequent disruption of family life and postponements of marriage—the effective fertility of the American people is likely to fall below the level required to maintain a stationary population. Evidently, our population policy must be given serious consideration in the councils that are guiding the nation through its problems in these difficult times."

SNOW PERILS AND AVALANCHES[1]

By Professor J. E. CHURCH

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AVALANCHES or "valleyward" snow are a mountain phenomenon born from the instability of the snow and early named from their spectacular descent into the valleys. Their latent peril to travelers and habitations has spurred detailed study of the evolution of avalanche snow until under the leadership of Wilhelm Paulcke, followed by Willi Welzenbach,[2] Gerald Seligman and the Swiss Avalanche Commission,[3] a science of snow structure has arisen.

Snow lies between water and ice in the degree of its instability but ultimately approaches the latter. Its cohesion, however, upon which stability depends, does not necessarily increase with age, but is rather a complex of several factors of varying degrees of potency active in the snow crystals and snow fields. Wide extremes for each with abundant exceptions must therefore be assumed.

FACTORS

Basic among all factors associated with avalanches is density, including porosity and friction, and these are directly affected by temperature, humidity, pressure and wind.

Density. The factor of density runs the gamut through wild snow, powder snow, packed snow, old snow or firn, and the sublimations, surface hoar and depth hoar.

Wild snow, the product of low temperatures (Seligman suggests $-15°$ C; 5° F) and perfect calm, has an initial density of only 1 to 3 per cent. and resembles down, with the ends of the plumes just touching. Powder or fluffy snow represents the earlier or loose-lying stages of fallen snow. The points of the crystals interlock and cause a certain amount of initial cohesion. Packed snow includes primarily cemented snow such as sun crusts and wind crusts. Old snow or firn is granular and usually compacted.

Surface hoar or ice petals provides a soft but stable surface particularly for ski but depth hoar or ice cup-crystals, which forms beneath crust deposits, acts as ball bearings beneath them when dislodged. This hoar known also as swim-snow is considered by Paulcke as avalanche material in itself.

The mean relative density of the various types of snow and their porosity is recorded by the Swiss Snow and Avalanche Investigation and Parsenn Service in the table on the next page.[4]

New snow may age quickly under high insolation or rain. The distinction between old and new snow is in crystallization rather than in time interval.

The figures in the table are for undisturbed snow. The porosity represents the vapor-saturated air between the crystals. The percentage indicates the freedom of vapor and air movement through the snow and its consequent effect in breaking down or rebuilding snow crystals.

[1] This is the fourth in a series of articles by Dr. Church on "The Human Side of Snow." The first appeared in February, 1937, the second in March, 1942, and the third in March, 1943.

[2] Pupil of Paulcke, who was lost in the German tragedy on Nanga Parbat, in the Himalaya.

[3] An avalanche film has been prepared by the Swiss Commission showing the technique of study and a supplemental film by the Swiss Army showing methods of rescue. Both are now in America in charge of the Internat. Comm. of Snow and Glaciers and the United States Quartermaster General's Office. A joint sound film is being prepared from the two. The former film is available for loan.

[4] Lawinen.

		Relative density (water = 100%)	Absolute porosity (% air content)
New snow	Wild snow	1–3	99–97
	Powder snow	3–6	97–93
	Weak wind-packed snow	6–10	93–89
	Strong wind-packed snow	10–30	89–67
Old snow	Depth hoar or swim snow	20–30	78–67
	Dry packed snow	20–40	78–56
	Wet packed snow	40–55	70–50
	Dry firn snow	40–70	56–24
	Wet firn snow	60–80	50–20
Ice		91.7	0

Temperature and Rain. The effect of temperature will naturally vary with the season, *i.e.*, with the angle of incidence of the suns rays to the snow surface. The higher the sun, the more rapid will be its effect in maturing the snow crystals. Thus summer snow passes through the same evolution as the snow of winter but far more quickly.

Furthermore, temperature changes are more abrupt and extreme at the surface of the snow than at depth. Freezing and thawing alternate at practically daily tempo as spring advances. Upward air currents in the snow deposit moisture at the surface and melt water is held in temporary suspension in the fernlike branches of the crystals.

A fall of temperature below freezing immediately creates crust and tension; a rise in temperature, as in cloudy weather, may persist sufficiently long to round the facets of the crystals and even provide lubrication. Rain will accelerate the process.

The crusts created primarily by temperature and rain are designated sun crust, rain crust, and film crust. The last is a very thin ice film over old snow.

Depth hoar is regarded by Seligman as resulting from the freezing and deposition of snow vapor rising beneath an impervious crust, the size of the crystals depending upon the amount of unobstructed space in which they form. Their counterpart is a dry granular firn, or corn snow, resulting from the sublimation of original snow crystals of an entire stratum.

Wind. In the Alps and mountains of western North America the prevailing wind is from the southwest. Consequently the drift snow is accumulated on the shaded slopes and thus receives partial protection from the sun.

Since the windward slopes are exposed to the full force of the wind, the snow there, except behind obstructions, is relatively thin. Since the speed of the wind is increased by compression at the crests and in the passes, the snow in adjacent areas is swept into the wind shadow on the lee, where it accumulates as snow cushions or "precariously perched drifts," and cornices. The latter are close-packed and cohesive.

Wind packing, as demonstrated by Seligman,[5] is possible only if the wind is humid and below freezing, for the packing requires cementing icing-up of the grains. If the wind is dry the snow will remain loose, though fine grained, as in snow cushions; but if the wind is moist, the snow without further movement will become compact.

Wind slab as contrasted with wind crust has rounder grains, indicating greater wear from drifting and is deposited mainly on lee slopes in the null-point of the wind to depths of one inch

[5] Snow Structure and Ski Fields. However, Robert G. Stone (communication) doubts this "as at night the coldness of the snow surface raises the humidity above it regardless. Have seen wind packing in dry wind as well as moist."

Ernie Mack

AN AVALANCHE AREA ON NORTH SIDE OF MT. LINCOLN (DONNER PEAK)

SPRING WET-SNOW AVALANCHES ON HARD CRUST, WITH PARTIAL BREAK-DOWN OF CORNICE.

Ernie Mack

QUIET SNOW AT MOUNT ROSE, NEVADA

to several feet. It is particularly unstable and prone to crack, partly perhaps because of expansion from driven snow and vapor but mainly because of the vacant spaces beneath it caused by the settling of looser snow and the consequent removal of support. The usual line of discontinuity between wind slab and the crust below and the frequent presence beneath it of depth hoar or swim-snow increases its tendency to slide if its marginal anchorage is broken.

Gradient and Slopes. The gradient of the slopes at which snow deposits are stable depends upon the friction or coherence of the snow crystals and snow strata. Snow slopes steeper than 22° must be regarded with suspicion, says Seligman, though old firn snow will be stable at 50°. But this is to be regarded only as a general rule, for wet snow avalanches have come down on a slope of only 15°.

He further suggests that the angle of repose for uncemented snow crystals may well be that of unconsolidated earth. Dry earth has a maximum angle of 29°, moist earth 45–49°, but very wet earth only 17°. Dry sand will lose cohesion only at 63°.[6]

The high cohesion of moist earth is evidently due to the slight film of water surrounding the grains and the loss of cohesion in wet earth to excessive water causing lubrication or floating of the grains. Likewise moist snow should be most cohesive and wet and water-soaked snow least. Wild snow, being almost impalpable, should lack cohesion entirely, while new powder snow, because of the interlocking of the plumes of the crystals, will be strongly coherent. Sand

[6] H. P. Boardman points out, however, that dry sand in the mass, where weight is a controlling factor, has an angle of repose of only 20° to 35°.

snow, whose facets are angular, should also be stable because of internal friction.

Plasticity. Compacted snow, though possessing cohesion, is subjected to internal stresses by its weight when lacking support. The resulting deformation may lead to fracture if forced too far. Haefeli[7] has found that, under similar load, compression in general has a far higher breaking strain than tension. On concave slopes, as the base of the declivity, compression will occur. On a slope of 33° snow is reported by Fankhauser to have crept eleven inches in thirteen days. However, because of decrease in friction the rate of creeping in various parts of the snow cover increases with height above the ground. If interrupted by rock ribs, shearing is produced. The pressure as on trees or other obstructions may be extreme.

[7] R. Haefeli, "Schneemechanik mit Hinweisen auf die Erdbaumechanik in Der Schnee und seine Metamorphose."

Change in temperature may create breaking strains as shadows strike a sun-warmed slope and cause expansion by freezing.

Anchorage. In the early winter, ground and trees may provide sufficient anchorage to prevent movement of the snow. Grass slopes, so dear to the herdsman in summer, are a peril in winter. In contrast, the brush in America provides comparative safety. But unless the points of control are sufficiently high to extend through the increasing snow cover, snow crusts may be formed above them and produce slip planes upon which newer snow may become very

Ernie Mack

DYNAMIC SNOW; PINNACLES OF MOUNT LINCOLN (DONNER PEAK) ABOVE SUGAR BOWL NEAR DONNER SUMMIT, SIERRA NEVADA.

LOOSE-SNOW AVALANCHES[8]
AT THE UPPER LEFT, BENEATH THE CORNICE, TWO AVALANCHES STARTED FROM NATURAL CAUSES; AT THE LOWER RIGHT, TWO AVALANCHES WERE LOOSED BY SKIERS.

unstable. Only when the snow falls sufficiently moist to be consolidated with the crust is the anchorage extended upward.

However, melt water later in the season may be caught by the crust and cause it to become a plane of discontinuity, lubricated for the descent of the overlying snow. Frozen ground, long grass, and flattened brush may act in the same way. Sometimes melt water from steeper slopes exposed to the more direct rays of the sun may accumulate on gentler slopes below and cause avalanches where less expected.

Types and Speed

In their most obvious forms avalanches fall into three main classes: (1) Loose-snow avalanches, (2) wind-slab avalanches, and (3) ice avalanches. But in the order of their seasonal appearance they are: (1) Dry soft-snow avalanches, (2) wind-slab avalanches, and (3) wet-snow avalanches. However, avalanche types are frequently complex and their season varies with elevation.

Loose-snow avalanches are less dependent on slide-strata than wet-snow avalanches and may result merely from an overburden of new snow. However, a hard-frozen under stratum will greatly increase their occurrence.

The most spectacular but rare of winter avalanches is the wild-snow avalanche that flows even through forests and, by its snow-dust, may suffocate a man at a distance or penetrate closed rooms out of its immediate path.

Snow cushions of loose powder-snow slip readily on the crust on which they were originally deposited. Steep slopes may make whole fields of loose snow unstable. Sun-balls caused by the moistening of cold new snow by the sun are often the forerunners of dry avalanches. The wind-slab avalanche has not only a slip crust but also frequently a depth hoar which accelerates its movement. But wet-snow avalanches are usually caused by warm moist winds that increase the density of the snow, break down the cohesion of the snow crystals, and provide melt-water lubrication.

Ice avalanches, akin to glacier cascades, occur above cliffs or steep rocks, and are usually a glacier product.

Blasts and Speed. The blasts that sometimes accompany avalanches and break off trees far above the ground and on either side of their course are caused both by the frontal thrust of the snow and the suction created by its passage. The prerequisite for blasts is a large cross-section of dense, swiftly traveling snow. As the velocity of the snow decreases at the foot of its slope, the blast may overtake it and travel far ahead, even to the opposite slope and cause an additional avalanche there.

[8] This picture is printed through the courtesy of Schweiz. Schnee- und Lawinen-forschung und Parsenndienst, as well as those on pages 415, 416, 419.

The speed of avalanches is dependent upon the type and volume of the snow and the smoothness and gradient of the underlayer. Dry powder-snow is fastest, damp snow is slowest. Owing to friction the speed at the sides and bottom is slower than that of the center. Hence the surf-like movement of the mass and the danger of being drawn under it. J. Coaz gives a mean speed of 350 kilometers (217 miles) per hour for the great Glärnisch powder-snow avalanche of March 6, 1898, on an average slope of 44°. In a total distance of seven kilometers the avalanche crossed a valley of 2 kilometers and climbed several hundred meters up the opposite wall and then flowed back. It started as a wind-slab avalanche. The descent lasted only a minute and twelve seconds but seven more minutes elapsed before the snow dust had settled. Mougin and Bernard estimate the speed of a wet-snow avalanche at seventeen miles per hour on a slope of 45°.

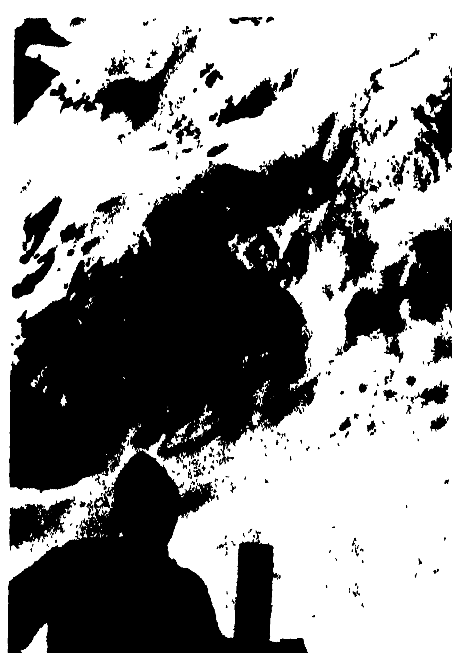
A volume of one million cubic meters, says Seligman, is not uncommon for both powder- and wet-snow avalanches.

Prevention and Avoidance

Avalanches can often be stayed at their source by creating an anchorage of contour trenches, terraces, walls, and screens of trees. Farther down their course, deflecting walls can be constructed to detour them or split them if buildings are in the path. Where avalanche danger is cumulative, incipient avalanches can be brought down while still ineffective by cutting or explosives.

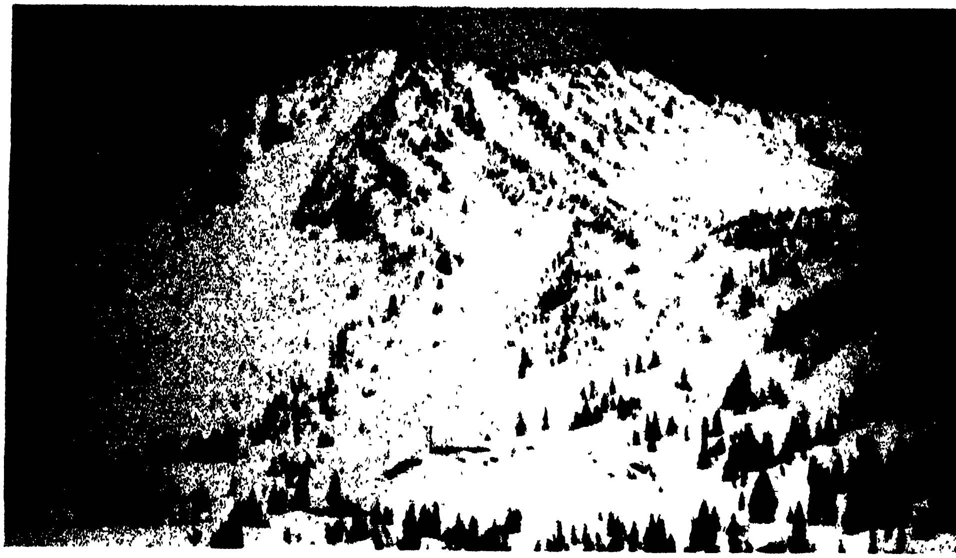
Avalanches can often be avoided by noting the nature of the snow and the character of the weather. Avalanches are most abundant in winter when the snow is unstable and storms are frequent and changeable. At normal winter temperatures dry-snow avalanches come down only six to twenty-four hours after snowfall, when the snowflakes are losing cohesion and one to two hours after the reappearance of the sun. In spring, during periods of sun, wet-snow avalanches may occur in the afternoon after the cohesion of the snow has been lessened. At night falling temperature will cement the snow again, but during a storm, avalanches may occur at any hour. However, no fixed rule can be given, for the impulse to avalanche movement is complex and difficult to foresee.

Testing and Forecasting. Tests of the tendencies of suspected snow fields can be made by perforating the snow to determine the cohesiveness of its crystals and crusts. Pauleke inaugurated the use of a snow sampler one meter long with windows. The Swiss Avalanche Commission has installed meters to determine the pressure or creep of the snow and uses a field ram to determine snow resistance or cohesiveness. Tests of both tensile strength and compressibility are



STARTING AN AVALANCHE

BY MEANS OF A TRENCH MORTAR. THE SHOT EXPLODED IN THE PART OF SNOW BANK SHOWN NEAR THE UPPER RIGHT HAND CORNER OF THE PICTURE.



Roy E. Lindquist

LITTLE COTTONWOOD CANYON, WASATCH RANGE, UTAH

SNOWSLIDES OCCURRED ON RUSTLER MOUNTAIN, AT LEFT, IN APRIL, 1941. NOTE THE ALTERNATION OF OPEN SLOPES AND CLUMPS OF TIMBER.

CONTOUR TRENCHING ON A SLOPE TO PROVIDE ANCHORAGE FOR SNOW

also made in the laboratory. Time profiles of the changing snow cover are kept.

On the foundation of such profiles, provided they can be used to interpret snow conditions at other elevations in the region, forecasts of avalanche tendencies under prevailing or impending weather can be made.

A hypothetical but classic forecast is given by Seligman:

"Feb. 3–5	Fine weather
Feb. 6	Thaw conditions up to 7,000 feet
Feb. 8	Rain up to 6,000 feet changing to
Feb. 9	Snow (8 inches fell at 5,000 feet) with S.W. wind
Feb. 10	Fine weather and temperatures of about $-6°$ C. (21° F.) at night

"The skier would know that up to 7,000 feet the snow of February 9th would be well bound to its underlayer, having fallen wet on a thawed or wet surface. Therefore it would be safe as soon as it had settled. This would occur in a day or two on south and in about three days on north slopes, no very low temperatures having been recorded.

"On north slopes, above 7,000 feet, the new snow would have fallen on old powder, the fine spell of February 3d to 5th not having been long enough to build a crust, except where the sun's rays fell. Therefore here, too, it would be safe if the total depth of powder were not excessive; but he would bear in mind that the eight inches which fell at 5,000 feet would probably be 12–15 inches at 9,000 feet, and more where drifted by wind, and this ought to be given time to settle.

"On south slopes above 7,000 feet all the snow that was coming down would have fallen off as avalanches, well within the three to four days' grace which the other conditions merited.

"Having made a note of the wind at the time of the fall, he would know, too, that most of the new snow on the south and southwest slopes would be blown away, or packed hard, but he would exercise corresponding caution on north slopes where the snow would be lying as wind slabs or cushions of great depth."

Rescue

Two novelties in rescue of snow-mountaineers should be mentioned for their extraordinary value. When traversing suspicious slopes the Swiss mountaineer unrolls a ball of twine that trails behind him to indicate the location of his body in case he is buried by a snow slide. As in drowing, resuscitation may be possible if not too long delayed.

In bringing a victim down from the snowfields, a toboggan, if available, is equipped with a pair of shafts made from his ski and ski-poles to steer and control it. Thus a single skier between the shafts can easily and quickly make the descent. Without shafts, dual control, front and rear, by ropes would be necessary and valuable time and strength thereby wasted.

If only one ski is broken and a ski companion is present, the mishap can be quickly adjusted by making up a three-legged party with the middle ski shared mutually between the two. A leg band provides the essential consolidation. By this means in the High Sierra Nevada a snow survey party made its escape in the face of night to the shelter cabin several miles distant. Mutual balance and control are essential but can probably be attained better side by each than by riding tandem on a single pair of ski. Dogs sufficiently small have ridden tandem to their master on a single ski, and a heavier dog rode contentedly in his master's knapsack.

The American Setting

Although the Alps because of their

Ernie Mack

A RESTLESS SNOW SLOPE ON THE NORTH FACE OF MOUNT LINCOLN (DONNER PEAK) IN SPRING

THIS SLOPE IS USED BY DARING SKIERS FOR A QUICK DESCENT TO DONNER LAKE, 2,000 FEET BELOW.

precipitous ridges is the home of the avalanche, many of the American ranges harbor perils as great but less expected. The sharp ranges of the Great Basin, such as the Wasatch of Utah, the Wallowa of Oregon, and the Ruby of Nevada, are spectacular and tragic. Winter mountaineers can select their time and their course, but winter habitations and snow-surveyors whose route and schedule are fixed have little or no deviation from latent danger.

In the Wasatch on January 30, 1911,[9] high up in Big Cottonwood Canyon "a slide began near the brow of a cliff where the wind for weeks had banked up the snows coming from the tops of the ridge. Breaking from its foundation under the influence of heavy rain, snow and slush rushed down the mountain, poured across a gulch, which had diverted all previous slides, ripped away long-standing trees, and rushed over a small secondary ridge to drop off the edge of an 80-foot sheer cliff onto the buildings of the Utah Mines Coalition Company. The momentum of the slide must have been tremendous because from the upper cliffs to the lower cliff the air-line distance is one-half mile."

In the Wallowa and Ruby Mountains evidence of avalanche speed has been found in trees sheared off midway by the blast and in the latter a snow-survey course in the floor of the canyon has been littered by snow débris. Parties should traverse the avalanche areas only at night or early morning while the snow is still frozen. Ultimately the snow surveyor will ride over them in an autogiro or helicopter to the safer snowfields above.

RESCUE TOBOGGAN ON DESCENT UNDER COMPLETE CONTROL

Two tragedies in recent years have occurred among snow-surveyors in the line of duty. Both were U. S. Forest Service men familiar with their routes and experienced in forest-craft. But their deaths were unintentional suicide.

In the Wasatch Leo M. Mayfield and two companions were traveling along a contour trail at 7,000 feet elevation where outcropping ledges of about 80 to 85 per cent. slope alternated with forested slopes of about 60 per cent. As reported to the author by George Stewart, "The snow seemed to be rather unstable and it is reported that one of the men

[9] Roy E. Lundquist, "Snowslides and Their Causes" (mimeo.), U. S. Weather Bureau, Jan. 31, 1941, p. 11.

Roy E. Lindquist

ALTA PASS IN WASATCH RANGE, UTAH

THE "COMB," OR CORNICE, IS 16 FEET HIGH. NOTE THE SNOW SLIDES BELOW.

was carried down the hillside 15 or 25 feet in a surface movement of powdered snow. The men continued on but finally decided to give up work for the day because conditions were unfavorable as it was snowing and low-hanging clouds prevented reasonable visibility.

"They retraced their course along the contour trail and then followed the edge of the timber to avoid the place where the snow had slipped slightly before. The party was so close to the timber that they probably could have reached out and held on to tree branches or kept a short distance inside the timber. Mayfield, who was leading the party, was apparently crossing over a rock outcrop which was concealed by three or four feet of relatively loose, light snow. The snow gave way with a report that sounded much like the explosion of a light field gun, and he was carried down the mountain so rapidly that his companions were unable to determine for the moment just what had happened. Then, too, the clouds, falling snow, and flying powdered snow obscured their vision.

"It is difficult to escape the conclusion that this was a freak accident and probably would not happen to another crew traveling the same country again in a thousand times. The point where Mayfield started the slide was limited to a small area of exposed rock probably not more than fifteen feet square, and it is believed that had he traveled only a few feet above or below this point the slide would not have occurred. His weight caused the snow on the rock to give way suddenly and a general slide occurred. There was no snow movement ten feet back of Mayfield where his nearest companion was located when the snow broke beneath him."

"The passage of the slide through a small group of fir trees and then on to an area covered with rather tall oak and maple suggests that slides are not common in this area. But prior snowfall had covered most of the chaparral and melting and cold weather had produced a very hard crust. Snowfall during the thirty-six hours prior to the accident had been heavy and probably two or three feet of powdered snow was deposited on

top of this crust. As near as we have been able to determine the slide was confined almost exclusively to the newly deposited snow which had no brush cover to maintain it and the slide passed down the frozen surface.

"It would be very desirable if a simplified code could be worked out to guide snow parties, as no doubt many men are assigned to this work with little previous experience. However, this was not the case with Mayfield and party, all of whom had had from one to four years' experience. Then, too, the matter of following prescribed trails needs to be more forcefully emphasized and compliance made mandatory."

The tragedy in the Jarbidge Mountains, Nevada, was fortunate in that two lives were not lost in place of one. Only by a rare combination of circumstances and superhuman strength did the second member survive and escape a lingering death.

Karl J. Wilkinson, Forest Ranger and Dale Rodies, miner, set out at the close of February on a four days' snow-survey trip to the head of Marys River Basin, Nevada. Both men were sturdy mountaineers and skiers. The summer route lay on the contour through Coon Creek Canyon rimmed above with pinnacles.

The day was mild but a light blizzard obscured vision and made close contact desirable. "Ranger Wilkinson remarked to Rodies that the snow appeared to be in

Dick Landis

PLASTICITY AND COHERENCE OF SNOW

MID-WINTER SCENE WEST OF DONNER PASS, CENTRAL SIERRA NEVADA (EL. BEACON HILL LODGE APPROX. 6,750 FT.)

Ernie Mack

NEW WET SNOW SLIPPING ON ROCKS AND CRUST

A SPRING PHENOMENON ON NORTH SLOPE OF MOUNT LINCOLN (DONNER PEAK). THE SLIDES PASS OVER THE RAILWAY SNOWSHEDS WITHOUT HARM.

very good condition and was safer from the standpoint of snowslides than he had found it during the previous two years." Wilkinson's dog was accompanying the party.

They were therefore proceeding with confidence along the summer route and were rounding the steep slope of Windy Point when Rodies found himself struggling in an undertow of snow. When at the point of suffocation he was thrown upward for a breath of air but was sucked back instantly to sudden oblivion.

After consciousness returned—he believes that it was fully an hour—he found himself pinned against a tree where air pockets in the snow had kept him alive. He struggled out with one ski still attached to his foot and the other broken. A few rods below he saw the tip of a protruding ski and followed it to Wilkinson's body packed head downwards in the snow. The other ski was lost. As he dug, he found a furry mat on Wilkinson's breast and threw it aside. It was the dog apparently dead.

A touch of Wilkinson's flesh showed the futility of further attempt at rescue. With his own face crushed in and weakened by loss of blood, he took the two remaining ski and struggled upward to the pass toward home. It would have been futile to proceed to the shelter cabin near at hand, for there was no telephone nor radio to summon help and anxiety would be felt by homefolk only after the lapse of four days.

He was haunted by dread that his strength would fail and night was near. At ten he staggered down into Jarbidge Canyon to the nearest light. How he escaped falling over the canyon wall was a mystery.

His hair is now gray, quickly turned by his agony. Rescuers on their return to the scene found the dog guarding his master's body.

At the final pass into Marys River Basin Ranger Tom E. Brierley, Wilkinson's successor, found avalanche hazards as great on occasion as the others enroute. The cornice here though solid in itself could harbor powder snow below and the slope was too steep to make the reascent vertically to avoid undercutting the snow. Since this pass is the only feasible entrance into the basin, a substitute snow course is being laid out on the hither side to be measured when it is not safe to go beyond. Instead of following the summer route through Coon Creek Canyon, all parties should detour up the bed of Coon Creek below the possible reach of any slide. A thousand feet down and up is a low price for safety.

The greater ranges of the Rocky Mountains, Sierra Nevada, and the Cascade have their tales. At Telluride, Colorado, the Ingram Basin harbors a nest of chronic slides that acquired names and made life at the mines a venture. A boarding house was carried away. Of the inmates and rescuers 21 perished and some bodies were not recovered until the following July.

The Ajax on New Year's Eve unexpectedly leaped over a cliff 700 to 1,000 feet high and sucked a new home into its vortex. The new mill manager who found void where he had expected his house to be immediately returned to the flat land of Chicago.

The Big Elephant because of its gentle slope had the characteristics of a glacier rather than a snowslide, but skiers across it could feel it move. Like the turtle and the hare, it outstripped the others in traveling five or six miles.

At Donner Pass in the central Sierra every evidence seemed to point to the consolidation of cornices beyond the possibility of release, as shown by the accompanying illustrations of cohesion on rocks and roofs. But a recent gale on Beacon Ridge at Soda Springs built out the cornice so rapidly that portions of it appear on the hillside like gigantic

snowballs stayed in their course and have become confused with the seven-foot play "snowballs" drawn up the mountain for filming an Abbott and Costello movie.

These balls should be kept distinct from the slides on the northern face of Mount Lincoln caused by late spring snow falling upon crust and melting. The pear-shaped forms are indicative of soft-snow avalanches.

That cornices may be treacherous is shown by the unexpected falling of the "Roman Wall" near the summit of Mount Baker in the Cascades and burying some of the members of an unsuspecting group of mountaineers beyond recovery.

The Original Safety First

The writer's life has been a series of adventures that have terminated fortunately, for even in his boyhood caution had been synonymous with safety last. But his dramatic introduction to safety first came early in an ascent of Mount Shasta—the first of the season—in 1896. The narrative has lain some years in manuscript:

"In 1896 to settle the question of the visibility of Mount Shasta from the summit of Mount Rose, Mrs. Church and I rode horseback along the crest of the Sierra Nevada from Lake Tahoe to Mount Lassen and Mount Shasta, a round trip of 600 miles and 31 days carrying our outfit on our saddles.

"The unknowns of the trip caused me to sweat in my bed on the eve of departure but the old assurance returned as we gradually threaded the route under the continuing guidance of the solitary dwellers of the mountains. I sweated again as we lay in sleeping bags close beneath Mount Shasta, which rose above us like the unscalable ramparts of Olympus,

"But the day brought increasing assurance as the heights slowly descended beneath our feet. On the long snow slope below the Yellow Cliffs, Mrs. Church had repeatedly fallen asleep from mountain sickness and as often I had galloped down the slope to overtake and bring back her heavy climbing staff which persistently slipped from her grasp whenever she sank upon the snow. Finally, she was left alone to climb more slowly to the Thumb at 12,000 ft., whence a clear view upward was had of the rounded summit of Mount Shasta and downward into the great gulf which seemed to undermine the Thumb itself. On a level with her eye stood the Yellow Cliffs, buttress of the summit, prepared like some titanic stage for the actors that were to come upon it.

"Meanwhile the guide and I had readily gained the top and were returning plainly silhouetted to her against the sky. The slope seemed gradual and we strode rapidly, swinging our staffs forward to steady our descent over shell ice which still carpeted the rocks.

"Suddenly my staff slipped from my grasp. Had I been too jaunty or had I underestimated the grip of a crippled hand? I could see the staff descending like a disappearing line toward the Yellow Cliffs beneath. Instantaneously I crouched, thinking to myself: 'If I can overtake that staff and thrust it in, I can stop and come back. If not, the staff and I will go over the cliffs together.' Then there flashed before my eyes the next morning's edition of the *San Francisco Examiner* bearing across its front page in four-inch letters:

THREW AWAY HIS LIFE FOR A PIKE

"I relaxed and gazed round to realize that the guide was burning a hole through my back with his blazing eyes.

"Suddenly the line drawn by my staff disappeared. Being staffless, I was forced to follow my guide on heels and wrists with stomach upward as the safest way of traversing the icy slope to the Thumb.

Ernie Mack

WINTER CONSOLIDATION OF SNOW CORNICE

ON HIGHWAY IN DONNER PASS. THE SNOW COVER WAS CUT AWAY BY A SNOWPLOW, BUT IT HAS BEEN REBUILT INTO AN OVERHANG BY COHERING DRIFT SNOW. THE FACE HAS THE STABILITY OF ICE.

"Here at the beginning of continuous snow, the guide started to glissade to lower levels with the curt injunction for Mrs. Church and me to follow. We now had only one staff between us but could lose no time if we were to overtake the rapidly disappearing form of the guide. With a bit of burlap, we improvised a toboggan with myself as steersman and brakeman. To our astonishment the snow was of a consistency to form avalanches that grew to moderate size but with quickly diminishing momentum. Thus by frequent change of avalanches created by leaping downward upon the snow, we overtook the guide even as he was untying the horses for the evening descent from timberline to the valley.

Roy E. Lindquist

A HUGE MASS OF SNOW

RESIDUE FROM A SLIDE LAST WINTER, PHOTOGRAPHED LAST MAY ON THE SOUTH SIDE OF LITTLE COTTONWOOD CANYON, WASATCH RANGE, UTAH.

"That autumn the staff was recovered at the base of the cliffs little injured by its fall of 300 feet and was forwarded to me as a memento. But like the silk pennant that fluttered at the head of my sleeping bag in later years on the Greenland Ice, unthinking and younger hands bore it off. Thus I have only my memory to keep me young. We failed utterly at the time to realize the dynamite upon which we were riding."

The Home Call

That we do not live unto ourselves was realized during the first winter trip made up Mount Whitney, the apex of continental United States, March 2–9, 1905, but only later was this thoroughly impressed by a member of the home community who protested against the undue worry caused to all.

The journal[10] was written in camp at Mirror Lake (10,450 ft.) where we sat out a storm.

Sunday Noon

"Our grove here is quite sheltered. We shall spread our sleeping tent[11] upside down on some tamarack supports by the side of a boulder and stay out the storm.

Sunday Evening

"In the shelter of the rock in the storm which has at last arrived in its full strength we sit and hope. It may be long or short, but to-night, at least, it has become a blizzard. The air is full of snow and the old tamaracks are powdery, while jets of snow are pouring from the rocks. The wind is whistling in the trees, and a fine sprinkle of snow is falling from our rock over us as we

[10] J. E. Church, Up from the Land of Little Rain to the Land of Snows, Sierra Club Bull. 7: 2 (June, 1909).

[11] The sleeping tent was torpedo in shape and split along the top for insertion of our two sleeping bags. It was designed for cowboy use on the range.

sit under its lee. The fire is casting its ruddy glow in defiance of the storm.

"I can scarcely see my lines because of the water on the page. So I shall just push the pencil through it. The page will dry later.

"This afternoon we went up the palisade to inspect the trail. Lone Pine Pass, where our route crosses the range at 13,000 feet, was faintly distinguishable in the clouds from where we stood above Mirror Lake. Across the amphitheatre arose majestic Crag Alexander Winchell, which broods over our camp.

Monday Noon

"The barometer remains steady at 10,400 feet.

"The snow seems to be so dry that the cold does not make it pack readily. Its drift, moreover, is considerable. We can make the ascent unless warm weather starts the snow slopes to moving or makes them insecure.

"I saw an eagle this morning as I lay in bed, soaring round the brow of Crag Winchell. He soon alighted there. He seems to have his eyrie on the crag. Marsh saw him soaring there two days ago, when we were at Lone Pine Lake.

Monday Evening

"The storm with its rear guard of slowly passing clouds has gone. Now we shall follow. A cold wind, however, is on to-night.

"I went to Lone Pine Camp this afternoon to bring up more flour and provisions, and a light tent. Our tracks of yesterday were drifted over in many places. I heard a bird today, but no more drumming grouse. This seems to be their mating season. As I was returning through Ibex Meadows, a faint halloo came floating to me down the mountain. My two hours' leave had elapsed, and Marsh was signaling. How weird the sound of the distant voice is when nature is so silent that the cracking of a twig sets the blood to surging.

CRAG ALEXANDER WINCHELL

EASTERN SPUR OF MOUNT WHITNEY FROM LONE PINE CAMP. "THE NOBLE CRAG NOW NEAR AT HAND WE HAVE NAMED CRAG ALEXANDER WINCHELL."

"Despite my weariness, I ascended the palisade to 10,800 feet to obtain a photograph of Lone Pine Pass and Crag Winchell. From this point the crag becomes a knife-edged spur terminating in a slight pinnacle. The wind had now risen and was sending the dry snow curling over the faces of the granite domes of which the palisade consists. The track of yesterday was covered, and I seemed to be wading in a mass of meal grown treacherous by concealing the icy, slanting granite surface beneath. The rope mesh of my Bavarian snowshoes alone made my footing at all secure.

"I finally waded through it all to where the last rugged but battered tamarack defied the wind. Stout it was but short, and its few limbs symmetrically grouped like an umbrella top. Here on a boulder overhanging Mirror Lake I placed my camera. There was small space to work on, and the wind was

stinging. Care had to be constantly exercised not to step backward into the yawning fissures nor slip forward into the amphitheatre below. I finally sat down on the boulder with the tripod astride my knees, but nearly succeeded in pitching the camera into my lap when I attempted to rise. I obtained, I hope, a fine cloud picture of Lone Pine Pass where the worst of our journey will be.

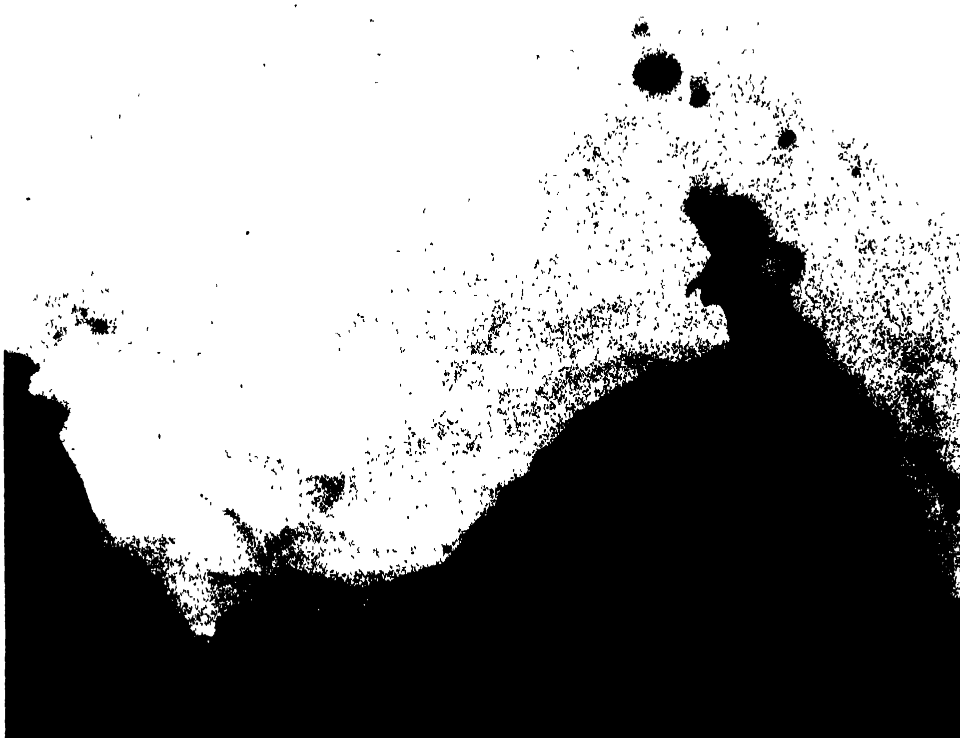
5 O'Clock, Tuesday Morning

"The gale of yesterday abated toward midnight. The stars are brilliant. The wind has veered to the southwest. The ground is frozen solid, but the snow refuses to harden. We are now ready to make the final attempt.

Tuesday Evening

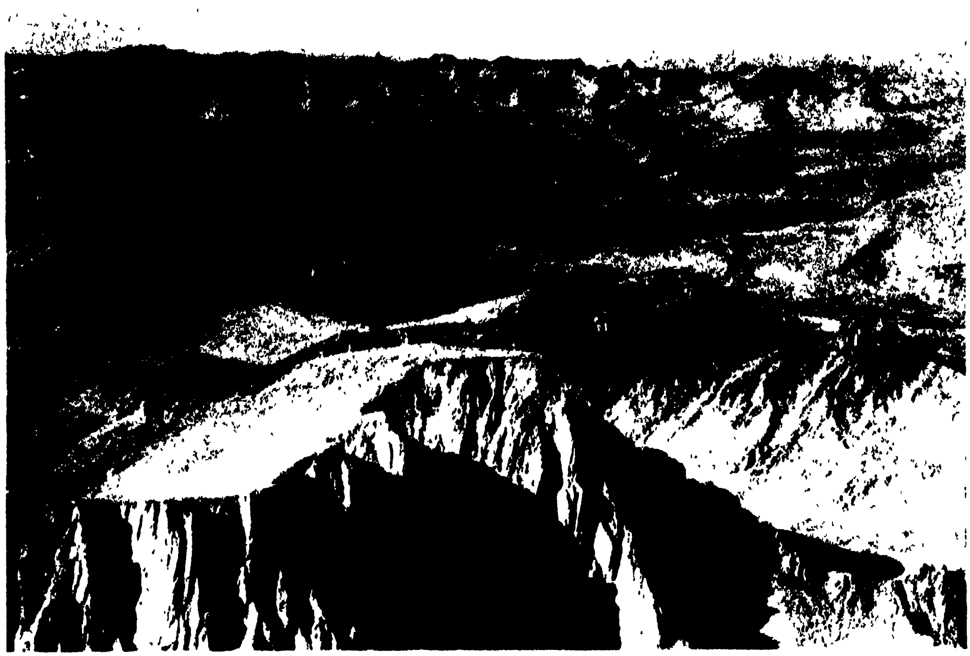
"We have met Mount Whitney's advance guard and retreated, but not without a skirmish. The snow was quite compact, after all, and we made fair time over it. At sunrise we could look down upon Crag Winchell. To the north lay Mount Whitney like a giant plateau uptilted toward the west. On its summit the monument could be plainly seen. But we were being forced to the south where the least steep slope of the amphitheatre gave access to the crest of Mount Marsh, up whose knife-edge of snow-capped rock lay our course to Lone Pine Pass.

"So steep was the slope and so deep the snow that we often clambered over



Dick Landis

DETAIL OF "PLASTICITY AND COHERENCE OF SNOW"
SHOWING STRATA OF WINTER ACCUMULATION WITH WEATHERING AND MELTING, WHICH ARE SLOW BECAUSE OF SHADING FROM THE DIRECT RAYS OF THE SUN.



Roy Curtis, photographer

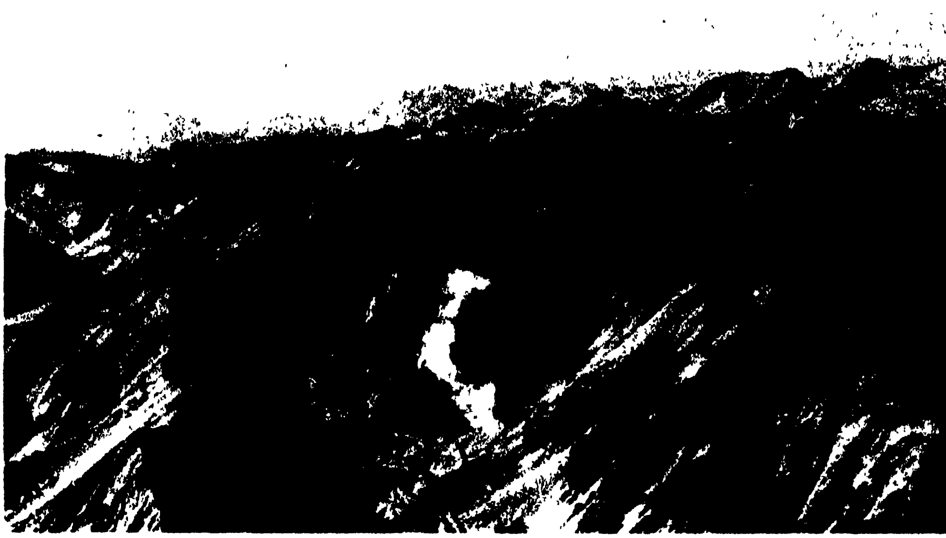
MOUNT WHITNEY (14,502 FT.) FROM THE AIR

SMITHSONIAN INSTITUTION OBSERVATORY ON POINT IN CENTER FOREGROUND. LONE PINE PASS IS BEYOND EXTREME LEFT IN FOREGROUND.

huge boulders whose height and depth were so concealed that we did not realize their size until the yielding snow let us slip back down their faces. Marsh had preceded me some little distance. When we were well up the knife-edge, I suddenly saw him standing in a tiny gateway of reddish brown rock to which a narrow path of steeply slanting snow afforded the only approach. This was the notorious slide to Consultation Lake which Marsh had feared. By hugging the wall and carefully tilting the inner snowshoe to work it through the narrow space left between my outer leg and the wall, I soon succeeded in gaining a place by Marsh's side in the pass. The barometer gave us the welcome information that we had attained the altitude of 12,950 feet, or only 1,500 feet less than that of the summit which we sought.

"To the westward, deep, deep below us, and extending, it seemed, almost across the State of California were frozen lakes, pinnacled mountains, and valleys, bare and desolate in the foreground and wooded in the distance—the whole one vast snowy panorama. Our route lay along the western side of the Saw Tooth Crags where a ledge along the cliffs afforded scanty room for the Lone Pine trail to reach the head of the Devil's Ladder, where it joins the Fresno trail to the summit.

"The field of snow below the pass slanted dangerously downward to the Cottonwood Lakes, but, trusting too much in our morning experience, we started to stamp our way across it. This time there was a strong crust below the drift snow, and our first plunge started ominous cracks in the snow above us. This meant avalanches. We immediately became more circumspect. Heel-thrust after heel-thrust, slowly repeated, as we faced outward and maintained a



Roy Curtis

A LAND-SLIP ALONG A FAULT LINE
IN THE HIGH SIERRA NEVADA, SHOWING THIS UNUSUAL PHENOMENON FROM THE AIR.

precarious balance on the slope, became exhausting, though we exchanged places every few rods. Often my pack overbalanced me, and a sudden fall inevitably resulted. But on every occasion the alpenstock, clutched rigidly by the head, was driven by the impact of my body its entire length into the snow and anchored me firmly. I sat upon it until Marsh stepped round my shoulders and beat a trail into which I could crawl to regain my footing. The slide of two thousand feet into the depression would have meant bitter exertion to return over such snow to our present level, and there was no wood nor had we more than a tiny lunch.

"The next slope was quite safe. Here we found Lake View Camp, the old high camp of the trail-makers, with abandoned camp stove and logs of wood. I suggested that we build a fire and spend the night. But Marsh declared that staying here over night would become permanent.

"So we hastened on, only to be almost immediately arrested by an ejaculation from him as he pointed to the next dangerous place—the ledge along the precipice. I offered to break the first part of the trail if he would break the second. But we soon realized that the condition of the ledge was dangerous far beyond expectation. The drifting snow had filled the ledge full and was even then sifting over the edge. For us to venture upon it would be to chance death in the abyss beneath, one to five. This was not a bad risk, however, but from a pinnacle that overhung the trail we saw that the ledge for fully a mile until it passed from sight around the shoulder of the mountain was in similar condition, and to continue would be to repeat the chance of going over every few rods. We had brought no shovel, and if we had the snow would have filled up the pathway behind us as rapidly as we cleared it ahead, or the snow would avalanche and carry us over the verge into oblivion, a kinder fate than imprisonment on the trail at 13,000 feet and higher on a winter night without shelter. We reluctantly decided that the remainder of the

journey along this route was impracticable, and our decision was attested by the dull boom of a rock that had rolled from the ledge at our feet.

"Our return was easy. The treacherous snow had hardened. But in the distant west masses of cloud were piling as high as heaven in fantastic forms like volcanic fires. Marsh had noticed the same formation the previous summer.

Lone Pine, Friday

"Tuesday night, following our attempt to gain the summit, a wildcat stole the bacon from the head of our bed. I could have tweaked its nose from where I lay, had I been awake. Marsh left scraps for it as assurance that he bore it no ill will. It was time for us to depart.

"Late Wednesday morning we started down the mountain. Ibex Meadow was firm for once. Those 'go-devil' sleds became pretty good little devils—stout little devils. They rolled over like cart wheels, side over side, end over end, down slopes through thickets along the bottom of the canyon. When the slope was fairly steep, we rode on the pack; when too steep, the sled rode with its runners in the air. One sled stood the test to the end. I nearly coasted over Lone Pine Falls in my enthusiasm. From Hunter's Camp, after hanging the loaded sleds in a tree, we tramped to Lone Pine. As we came up the lane through the willows in the darkness, a silent figure in white waiting at the bars came swiftly to meet my companion, while a little tow-headed fellow in the home gave him a hug that was enthusiasm itself. I was glad then that I had not urged him out along that cliff. The call of the wild is strong but the home call is stronger."

There are, however, moments in life that transcend life itself—visions that none other or few have witnessed. Of these is the vision—mostly inward—of Simpson and Odell[12] from Nanda Devi (25,645 ft.), the highest mountain on earth yet conquered by man: "After three-quarters of an hour on that superb summit, a brief forty-five minutes into which was crowded the worth of many hours of glorious life, we dragged ourselves reluctantly away, taking with us a memory that can never fade and leaving behind 'thoughts beyond the reaches of our souls'."

[12] H. W. Tilman, The Ascent of Nanda Devi.

MEDICINE BRANCHES OUT

The New York Academy of Medicine properly regards itself not only as a society of physicians but as a social institution. Its offices are needed in these days of storm and stress. Doctors and nurses are leaving in droves for the front. New occupations with new health hazards have appeared with new industrial processes. More women are entering the factory.

It was therefore natural that the Academy's recently elected president, Dr. Arthur F. Chace, should emphasize in his inaugural address the responsibilities that must be faced by medicine at a time when health and morale are inseparable. But he does more. Though the physician will always minister to the individual patient, he must learn to regard himself as one of the many architects of our culture. We live in a mechanized world by the grace of the physician as well as by the grace of the chemist and engineer. Accordingly, Dr. Chace sketches a program of action which calls for more than the efficient treatment of individual cases of disease. He is concerned as much with the post-war world as with immediate needs. Medical education, the plight of voluntary hospitals that can no longer count on substantial philanthropic support, the relocation of migrant populations, the proper distribution of medical services, the effect of nutrition and the occupational environment on masses of people—all these are to be studied by appropriate committees. Nothing more ambitious has ever been proposed for the consideration of a private medical organization in this country.—*The New York Times, January 9, 1943.*

WHEAT RAISING IN THE VENEZUELAN ANDES[1]

By Dr. RAYMOND E. CRIST

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To the middle-latitude dweller the low latitudes or tropics are usually synonymous with vast areas covered by impenetrable rain-forests, whereas in reality climatic conditions are greatly modified by mountains everywhere in the world. The tropics are no exception to this rule, and the tropical mountains are responsible for well-demarcated altitudinal life zones, so that in a few hours by car it is possible in ascending a mountain in the tropics to traverse all the climatic regions, say, between the tropical rainforest of Cuba, across the United States and Canada, to the tundra of Alaska.

In the tropical lowlands bananas and sugar-cane grow well, at about 6,000 feet many of the crops of the so-called temperate zone thrive, and at 8,000 to 10,000 feet potatoes and wheat are important crops. The wheat farmers around Mucuchíes, in the upper Chama valley of the Venezuelan Andes, are marginal on the four counts of temperature, fertility, slope and precipitation. One must travel hundreds of miles to cross the transition zone between the rolling wheat-fields of Iowa and the sand-hills of western Nebraska, farther still to the steep infertile slopes of the Rockies or the soggy treeless tundra north of Lake Winnipeg. Yet the wheat farmers of Mucuchíes are almost within a stone's throw of any one or all of these transition zones, which in width are lines, not belts, and beyond which farming is out of the question. One part of a field may be so rocky that plowing it is merely a process of temporarily changing the positions of the stones, another so steep that there will be a difference in elevation of three or four feet between the two oxen pulling the plow, still another so high and cold that in a year of exceptional cloudiness the crop will not mature. And the whole area is apt to suffer from drought in dry years.

Shortly after the Conquest many Indians were settled on reservations set aside for them called Resguardos de los Indios, and they worked the soil on a cooperative basis for several centuries. These reservations were put on the open market in the eighties of the last century and sold to individual farmers, usually in small plots. Where the soil is particularly infertile and the steep slopes have been incised by deep gullies, the whole cultural landscape has a shabby appearance. Much of this kind of land is passing from small to relatively large owners and is being devoted more and more to pasture than to crops. As a result it will continue to be economically valuable indefinitely. But the changes of tenure in this area are of less importance than what appears to be a slight change in climate. In the old documents in which lands around Mucuchíes are described, mention is often made of *juncales,* or tracts where rushes abound. At present no juncales exist. The whole landscape has taken on the aspect of an area characterized by a middle latitude steppe climate.

Areas above the 6,000-foot contour, *tierras frias,* yield only one harvest a year. Some soils are especially rocky, others are called *pulpas,* because of their thick layer of humus and their freedom from rocks. In certain areas the land

[1] The field work on which this article is based was made possible by grants from the John Simon Guggenheim Memorial Foundation and the Graduate Research Board of the University of Illinois.

INTENSIVELY CULTIVATED ALLUVIAL FAN IN HIGH VENEZUELAN ANDES
IN THIS WHEAT-GROWING AREA, PARTITIONED BY STONE FENCES REMINDING ONE OF NEW ENGLAND, NEAR-FREEZING NIGHTS ALTERNATE WITH SUN-DRENCHED DAYS.

OLD-FASHIONED THRESHING TECHNIQUES IN THE MUCUCHIES REGION
AS THE WHEAT IS SEPARATED OUT BY THE HORSES' HOOFS, THE STRAW IS FORKED AWAY.

has been farmed out, in others it is still remarkably fertile. Particularly infertile fields are allowed to lie fallow (*barbechado*) for a year after the harvest, between October and December. Oxen are pastured in such plots, and find a few sprigs of wild oats to feed on. Nothing further is done till August of the following year, when it is plowed again. In areas which are cropped each year, without fallowing, the plowing is done in March or April, preferably after an *invierno* (shower). The plough is of the old Roman type, a long wooden beam with a stake driven through it, which barely scratches the surface. The wheat is sown broadcast, and the grains are usually covered by plowing again, or by hand, with a small shovel or paleta. In small plots and on the edges where oxen can not enter, the grain is always covered by hand. Often the stand is too thick, and the competition between the plants is so great as to hinder their proper growth and development, thus diminishing the yield.

The use of a plow which merely scratches a shallow trench as it goes means that some of the grains are covered by so much earth that the sprouts are unable to reach the surface, and thus much seed grain is wasted. And in rocky fields much seed is lost under the stones.

Once the grain is covered the farmer's task is done. The growth and maturing of the crop depend largely on the temperature and the amount of rainfall. In a few instances weeding by hand is done when the wheat is about a foot high. Ferns, *hoyo* (*Lolium temulentum*) and other weeds are cleaned out. But the wild oats (*Avena* sp.) is not, because the millers, who in the Andes have stone mills, have a preference for wheat with oats; they say it whitens the flour (*blanquea la harina*). It probably does tend to keep the flour dry and free from mold. At all events most farmers allow this pest to grow freely with their wheat.

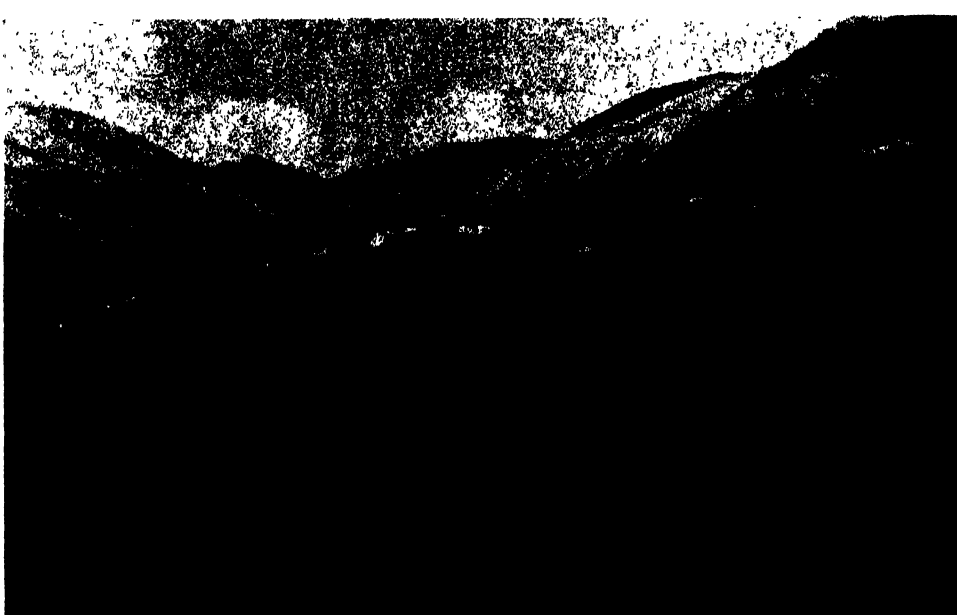
The harvest takes place between September and December, depending on the elevation. The wheat is cut by hand with a sickle. The day of the harvest is one of the big days of the year. Every one enjoys this all-out effort. The tiny

WINNOWING THE CHAFF FROM THE WHEAT IN THE UP-VALLEY BREEZE

sheaves, bound by hand, are piled up, tied into big bundles with ropes, and then carried on human backs to the stacks. When it has thoroughly cured, the grain is threshed out by the age-old practice of driving horses or oxen over the sheaves till the grain has loosened and settled to the ground. The threshing floors (*eras de trillar*), of tamped earth, are surrounded by a stone fence. When the weather is favorable the sheaves are spread out on the threshing floor and the animals driven in. If oxen are used they are hitched to a sled on which is a heavy stone. This they drag round and round. If horses are used their hoofs are sharp enough to effect the separation of the wheat from the straw and chaff. One man urges them on with a long whip and loud shouts, and after several hours the process of threshing is over.

When the wheat is threshed, the straw is forked off, and the wheat is separated from the chaff by winnowing in the wind. The mass is thrown in the air. The wheat falls back on the threshing floor, and the chaff is blown outside. Then the wheat is swept up, put in sacks of *cocuiza* (fiber of the *Fourcroya Humboldtiana*) and stored—usually in the dwellings themselves. The well-to-do farmers put the grain in enormous sacks of canvas or *cocuiza* which hold 20 to 30 quintals—one quintal equals 46 kgm—or in huge bins, with an opening in the lower part from which the grain will pour when a little trap-door is opened. The poorer farmers pile the wheat in a corner of the house, and if it gets damp it is placed on cowhides and dried in sun in front of the house before being taken to the mill. With such threshing techniques all kinds of impurities are mixed with the wheat, making it of inferior quality. A later cleaning often means a loss in volume of 10 to 15 per cent. of the original quantity.

Thus in these cold, bleak highlands, so unlike what we always imagine a tropical landscape to be, thousands of people spend all their lives in the process of getting barely enough to eat. Almost all the work is done by hand: planting, harvesting, threshing, transporting to the house, and later to the mill. Only in the ploughing is the poor farmer aided by



WATER MILL AT SAN RAFAEL

the patient ox. But the most regrettable factor of all is not that all energies are devoted to making just enough to keep body and soul together, but rather that when everything produced in a given area is used up almost at once, the possibility of capital saving and accumulation, and the subsequent improvement in farming technique thereby made possible, is either remote or entirely out of the question.

TYPICAL MIDDLE CLASS FAMILY IN SAN RAFAEL. NOTE EROSION GULLIES IN STEEP WHEAT-FIELD IN THE BACKGROUND.

Is there a solution to the problem presented by these people who are engaged in what in many countries would be considered submarginal farming? That it can not be solved if regarded as a purely local problem would seem to be self-evident. What then can be done? The state can impose a high tariff on wheat which will make it possible to keep the prices of Andean wheat high. But as the Andean agricultural population increased the tariff on wheat would have to rise in proportion, a rise that can not go on indefinitely if the good of the rest of the Venezuelans is to be considered at all. It would seem certain long-range plans will have to be worked out. The present arrangement is uneconomic in the extreme—thousands of people are precariously anchored in areas that barely feed them. If the good of these people is the desired end, many of them must migrate. The question is, where? They must find employment in public works—roads will pay for themselves many times over in a short time—in industries, which may be either privately or federally owned and operated, or on land still to be wrested from the rain-forest or "jungle" in the hot lowlands.

The state can and does commandeer wealth, people and their services in the task of defending itself against enemies from without. But there may be potential enemies within a state more dangerous to its continued existence than those beyond its borders. Hungry individuals, either submarginal farmers in a rural slum or unemployed workers in the slums of a city, are the vandals created by advances in technology in the twentieth century. They have only to find work to be reintegrated into their society, to become forces working toward close-knit union instead of centrifugal forces working toward disunion.

Higher still than the wheat, above the upper limits of cultivation a few wandering shepherds graze their flocks. This is the *paramo*, the epitome of sterility, of death. A stream that now meanders across the over-deepened bed of a former glacier babbles along to the placid lake formed behind the terminal moraine. The water is ice cold, and the whole landscape seems to cry out that it has lost, or never had, its fructifying power. There are no trees. The air is clear, the sky as blue as any sky of Italy above the great peaks, democratic in their 13,000 feet elevations. Here one feels dwarfed, overcome by the magnitude of the rugged Gothic peaks that silently strive upward

TRAIL ACROSS THE HIGH TREELESS PARAMO AT APARTADEROS

NOTE MEANDERING STREAM FLOWING INTO GLACIAL LAKE, AND TERMINAL MORAINE TO RIGHT.

EARLY MORNING DOWN-VALLEY VIEW

FROM THE AGRICULTURAL EXPERIMENT STATION AT MUCUCHÍES. THE HARSH TREELESS LANDSCAPE HAS MANY CHARACTERISTICS OF A MIDDLE-LATITUDE STEPPE, COMPARABLE, EXCEPT FOR THE RUGGED RELIEF, TO THAT OF THE DAKOTAS.

toward the infinite. This tropical tundra supports prickly mosses and hardy shrubs a foot or so high. The lion's share of the vegetation consists of the velvety-leaved *frailejon,* a giant dandelion, the white or cream-colored center leaves of this mullen-like plant forming the only bright note in a grayish drab landscape. The frantic pounding of the heart at the slightest exertion makes one too keenly aware of the elevation. But nature is not only inert but almost soundless. No song bird cheers the traveler with his notes. A few flies get warmed up enough to buzz around a few hours at mid-day. The actinic rays of the fierce tropical sun, with only clean thin mountain air to act as a filter, mercilessly scorch even the toughest skin. Yet shade temperatures never get much above 50 or 55° F.

But the narrow *paramo* at Apartaderos is traversed not alone by a few nomadic shepherds. The narrow white line seen in the distance is a trail, along which moves slowly a train of pack mules followed by the driver in his heavy *poncho* of gray wool. This narrow strip of land separates two geographic units which are well developed—the fertile Chama Valley and the great grass plains, or Llanos, of the Orinoco Basin. The potatoes, wheat and temperate zone vegetables from the mountains move across this *paramo* to the plainsmen on the other side, and the cattle from the sparsely populated Llanos cross here on the way to the slaughter houses in the densely populated mountain valley. The pack trains and herds of cattle have worn smooth the trail across this 10,000-foot pass. A highway would facilitate this exchange, but trade does not wait on the construction of highways, and is no respecter of what might be considered "insuperable barriers."

CUTTING WHEAT BY HAND
ON THE STEEP, ROCKY INFERTILE SLOPES NEAR MUCUCHÍES.

GASOLINE FIRES OF ELECTROSTATIC ORIGIN

By Professor ROBIN BEACH

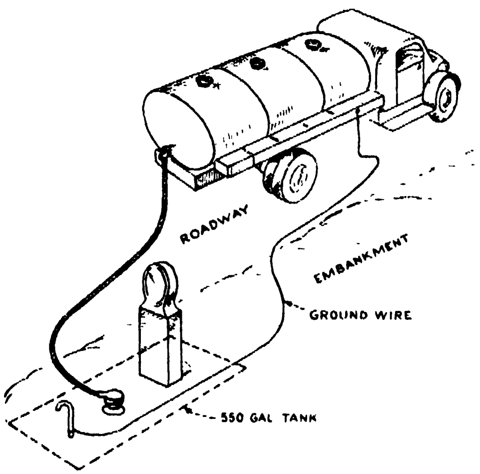
HEAD OF THE DEPARTMENT OF ELECTRICAL ENGINEERING, BROOKLYN POLYTECHNIC INSTITUTE

In these heydays of the saboteur, implements of war are being stealthily, but nevertheless systematically, destroyed in their making by the human agencies of inimical forces. Where future malicious attacks by these diabolical powers may occur on the home front can be neither predicted nor anticipated—a typical uncertainty that is characteristic of the human element. This is not so, however, of certain physical agencies which likewise are active sources of costly destruction, and which are also effective forces in impeding the progress of war-time industrial schedules. Being physical, rather than human, agencies, their behavior under prescribed conditions is capable of accurate prediction, and yet through the repetitious attacks of an errant physical agent, such as static electricity, for example, inexcusable economic and human losses are permitted to occur —losses which accumulate into alarming annual proportions. These resources could largely be conserved by the practice of preventive measures rather than by condoning destruction and then applying costly remedial methods.

Sparks resulting from electrostatic discharges have blown up munitions plants, and they have fired or exploded factories devoted to the manufacture of cereals, starch, sugar, chocolate, paper, powdered aluminum and magnesium, rubberized fabrics, sulfur products, anesthetics and textiles—to name only a few of the more common examples. Fire losses in industry, which originate from the electrostatic sparks produced by industrial belts alone, aggregate approximately four million dollars per year. Petroleum distillates, in manufacture, in transportation and in use, top the list of products most susceptible, as a group, to the fire and explosion hazards of static electric sparks, and since gasoline is one such petroleum product which is manufactured and used in vast quantities, naturally the number of fires from this cause is relatively large. Generally direct evidence of the origin for these fires, if any existed, is destroyed in the burning, and the investigator of these casualties is confronted with perplexing problems in attempting to establish a strong and irrefutable chain of circumstantial evidence. He may glean his information in part from careful and critical observation, and in part from theoretical research—strengthened, when possible, by the corroborative support of laboratory tests.

The fires from electrostatic origin, strangely enough, almost invariably occur by reason of the violation of some well-recognized safety practices. The importance of this situation, which so often leads to costly fires, is illustrated in this article by the citation of a number of cases where fires of strange origin, appearing even mysterious at first, have been traced to static electricity.

Case No. 1. A tank truck was driven into an estate one dry spring day to deliver an order of gasoline to an underground 550-gallon storage tank at the side of the garage. The driver, a careful operator, went through the approved routine of connecting the grounding wire from the truck to the vent pipe of the tank; then he inserted the nozzle of the hose into the fill pipe of the tank; and after this, he connected the other end of the hose to the outlet of one compartment of the truck. This done, he opened the discharge valve at the truck which permitted the gasoline to flow into the tank.



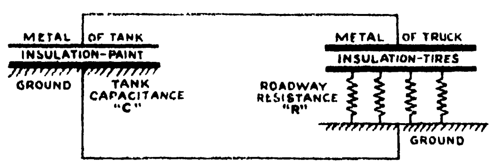


FIG. 1. "ELECTRICAL CIRCUIT"
THIS DIAGRAM SHOWS THE APPROXIMATE EQUIVALENT CIRCUIT BY WHICH ELECTRICITY FLOWS FROM THE CHARGED TRUCK TO THE UNCHARGED UNDERGROUND TANK. THE HIGH RESISTANCE "R" OF THE DRY ROAD BED, REDUCES THE FLOW OF ELECTRICITY TO A MERE TRICKLE OF ABOUT 10^{-8} AMPERE.

In about a minute and a half, after about 75 gallons had been discharged, fire burst out of the vent pipe.

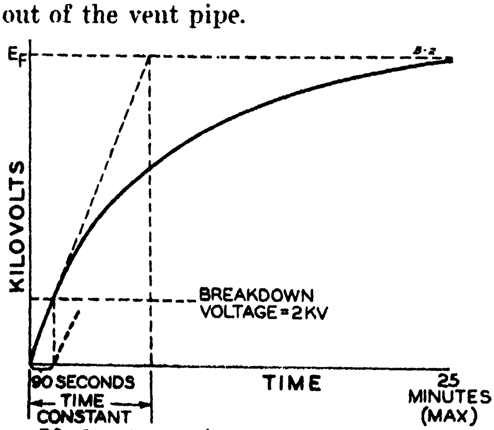


FIG. 2. THE GROWTH OF VOLTAGE ACROSS THE CHARGING TANK CAPACITOR. THE PAINT INSULATION WAS PUNCTURED AT ABOUT 2,000 VOLTS, AND THE ENSUING SPARK IGNITED THE INFLAMMABLE GASOLINE VAPOR-AIR MIXTURE AFTER ABOUT 90 SECONDS OF GASOLINE FLOW.

The alarmed driver, who was near the front end of the truck preparing the sales slip, quickly shut off the valve, started the engine and drove out of danger. The fire subsequently spread to the garage and other buildings, however, and extensive damage resulted. The cause of the fire gravitated into an ostensible mystery to various eminent investigators as each eliminated, one by one, all the possibilities of the ordinary sources. The author was finally called upon to study the problem and to determine, if possible, the cause of the fire.

Suspecting static electricity as the incendiary agency, the author conducted a lengthy research into the then unknown factors basic to the electrification of rubber-tired vehicles. The study showed that a large truck running on a dry highway could readily become electrified to the high voltage of 15,000 to 25,000, or more, volts from the friction of the tires with the roadway, and that subsequently the truck body, at standstill, could retain much of the electric charge, under favorable conditions, even for hours.

An amazing discovery showed the underground tank and its connected pipes to have been inadvertently, but nevertheless thoroughly, insulated from the ground by the multi-layers of titanium oxide and asphaltum paint. This particular type of paint was found by chemical and electrical tests to serve as an excellent dielectric, thereby causing the tank to become an electric capacitor in which the insulated metal formed one of its plates and the ground the other. In addition, the truck body with respect to ground constituted another—a charged—capacitor, in which the metal of the truck and the ground was effectively insulated from each other by the dry tires. The capacitance of the truck for storing electricity was of the order of 800 micro microfarads while that of the storage tank was about half this value. As the ground wire and the wire-enmeshed hose conductively connected the truck to the insulated tank, electricity began to flow,

in a trickle, from the highly charged truck into the uncharged tank capacitor. The physical arrangement of the truck and tank, as well as their equivalent electrical circuit, are shown in Fig. 1.

The growth of the charge which accumulated on this underground tank capacitor was, in this instance, very slow because the series resistance interposed into the electrical circuit by the intervention of the dry roadway materials was exceedingly great, and, in consequence, the resulting voltage between the tank and the ground also increased slowly. This voltage characteristic is shown in Fig. 2. As the voltage attained a sufficiently high value, about 2,000 volts, to puncture the insulating paint, the ensuing spark ignited the combustible mixture of the expelled gasoline vapor and air which had seeped into the interstices of the soil about the tank. The flame was at once propagated back to the source of the outflowing vapor through the vent pipe of the storage tank.

Had the tank not been insulated from ground by the paint, or had the vent pipe extended to a height of ten feet above the adjacent buildings, in order to dissipate the vapors harmlessly into the atmosphere, the fire could not have occurred.

Case No. 2. In this instance a tank truck was likewise delivering gasoline into a 550-gallon underground storage tank at the filling station of a large garage. The driver maneuvered the truck into position near the fill pipe, which extended about six inches above ground directly alongside the main entrance to the garage. The hose was connected in the customary manner—the loose nozzle being placed in the fill pipe first, and then at the other end screwed to an outlet from one of the compartments of the truck. No grounding wire for the truck was provided in this case. In about a minute and a half after opening the valve at the truck to discharge the gasoline, fire burst out of the combined fill and vent pipe, burning balloon-shaped to a height of about five feet. Before it could be extinguished, the driver excitedly threw the hose out of the fill pipe, spreading gasoline and flames into, and around the front of, the garage. The ensuing fire completely destroyed the garage and showrooms, both containing several vehicles, a lubritorium, quantities of supplies and the office.

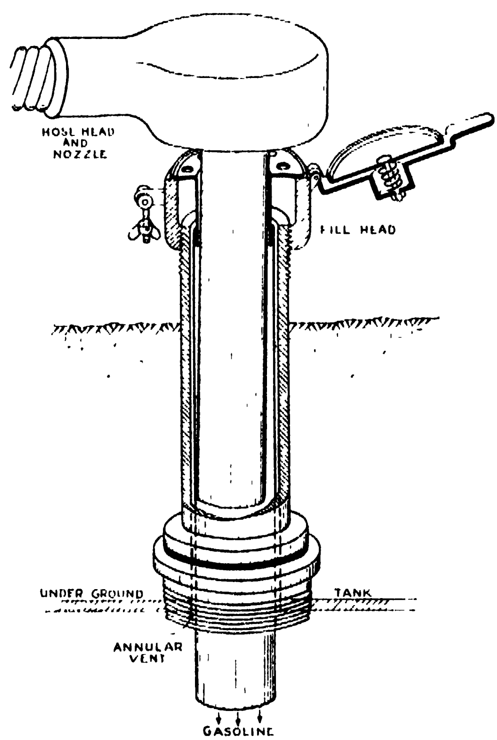


FIG. 3. COMBINED VENT AND FILL PIPE SHOWING: (1) THE HOSEHEAD RESTING ON THE RUSTY AND DIRTY FILL HEAD, (2) THE POSITION OF THE HOSE NOZZLE IN THE FILL PIPE AND THE LOCATIONS WHERE THE SPARKS COULD OCCUR, AND (3) THE GROSS INADEQUACY OF THE ANNULAR VENT HAVING ABOUT 1/15TH OF THE CROSS-SECTION OF THE FILL PIPE.

In the absence of any ordinary sources of ignition of the mixture of gasoline vapor and air, the origin of this fire also seemed a complete mystery. Although the engine of the truck was allowed to run, ill-advisedly, during the transfer of the gasoline, nevertheless it was eliminated as a likely cause of ignition. When the author made his investigation of the

premises, performed certain electrical tests, and learned what pertinent facts were available, he believed static electricity to be the cause of the fire here, too, largely because of certain peculiar circumstances which he discovered.

The use of the combined fill and vent pipe, as illustrated in Fig. 3, is a violation of the safety codes of every oil company and protective agency in America. This combined unit was installed many years ago when gasoline was laboriously bucketed from the trucks, and it was not changed with the advent of the modern high-speed filling operations which commonly employ two-inch hose that discharge gasoline at the approximate rate of fifty gallons per minute. This vent pipe, whose discharge area was less than 7 per cent. of that of the fill pipe, was utterly incapable of venting the tank while it was being filled, and so the gasoline vapor exhausted from the tank, in addition, through the fill pipe—causing gasoline spray to be carried upwards and producing a most hazardous condition for the starting of fires.

While gasoline was flowing through the hose line, it acquired by friction a positive electrification, electricity which discharged to ground as rapidly as the gasoline entered the tank; but the corresponding negative electrification in the hose was impounded there and on the metallic structure of the truck, in part, because of the insulating properties of the tires and the dry roadway, and, in part, by an unanticipated phenomenon which occurred at the hose nozzle. The nozzle was an oxidized section of pipe of one and three-fourth-inch diameter which extended about twelve inches down into

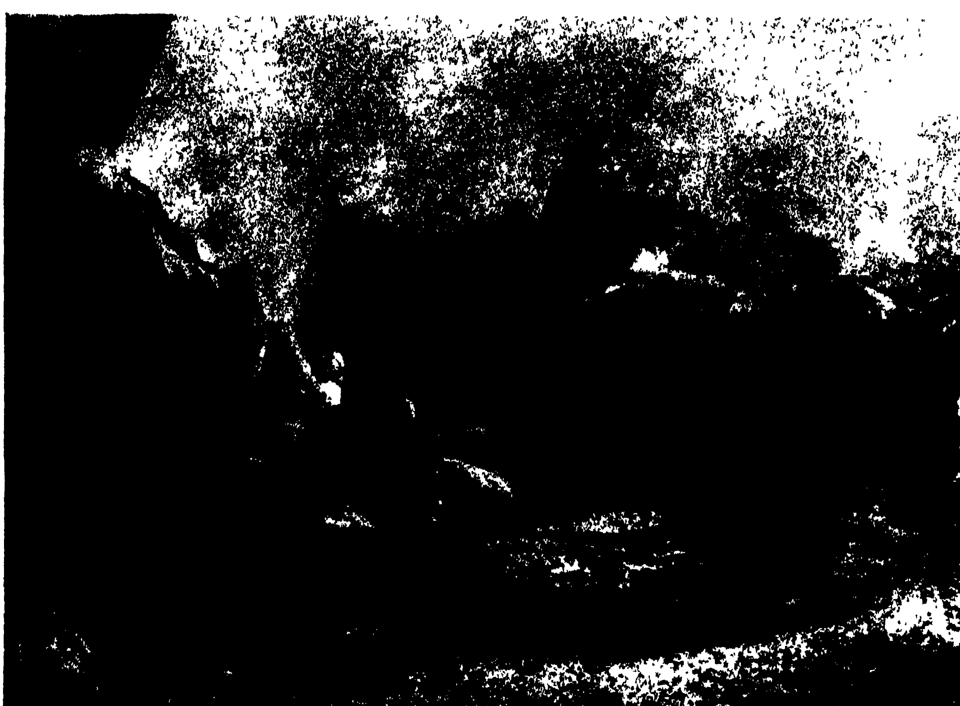


FIG. 4. DESTRUCTION OF TWO GREAT LEVIATHANS OF THE HIGHWAY ON THE LINCOLN HIGHWAY. THE TRAILER OF AN ARTICULATED GASOLINE TANK TRUCK (SHOWN ON THE RIGHT) WAS EXPLODED BY THE ELECTROSTATIC SPARK FROM A LARGE PASSING TRANSPORT CARRIER (SHOWN AT THE LEFT). EVEN THE CONCRETE HIGHWAY FOR 100 FEET WAS RUINED BY THE INTENSE HEAT FROM THE INFERNO OF BURNING GASOLINE.

the two-inch fill pipe. Where the hose head rested upon the rusted steel plate which formed the head of the fill pipe, the interposed oxides and grains of sand or dirt would effectively insulate the hose head from the fill head; and, in addition, the lower end of the nozzle would be insulated from the fill pipe by the intervening films of the splashing gasoline—as laboratory tests proved conclusively that gasoline was an insulating fluid considerably superior to the best grades of transformer oil. The impounded negative charge on the insulated truck body and hose increased in amount about proportionately with the flow of the gasoline until, finally, the resulting voltage to ground attained a value of several thousand volts, sufficient to cause a spark from the hose nozzle either to the fill head or to the fill pipe within. This spark initiated the fire.

Here, too, the fire could have been prevented by the employment of safety practices long since recommended by the National Board of Fire Underwriters and other safety-promoting agencies. The use of a grounding wire, during the unloading of the gasoline, from the truck to an appropriate ground terminal, say on a water pipe, would have caused the discharge of the negative electricity as rapidly as it formed. Or, had the vent pipe from the tank been a separate pipe, discharging the vapors harmlessly into the air at the recommended distance of ten feet above the roof of the garage, fire would probably not have occurred. The most effective means of all, though, and one which actually eliminates the hazard of fire, would have been that of the "screw-in" type of hose nozzle, as now required by law in several of the large and more progressive cities. This, unlike the loose type of nozzle, screws into the fill pipe to form a perfect ground for the discharge of static electricity.

Case No. 3. A certain new garage of a large public utility, which accommodated and served about two hundred automotive vehicles, had just opened for business. During the first week of operation, an example of ill-advised practice in the simple process of refueling automotive vehicles, in this case an executive's luxurious car, served to drive home a lesson in "safety first." The car was driven into the garage property one crisp winter's afternoon, stopping at the out-of-door gasoline pumps for refueling. The attendant, who was new at the job, first removed the cap from the fuel tank of the car, and then reached for the fill hose. As he brought the hose nozzle near the tank, a spark jumped from the highly charged car to the grounded hose nozzle, ignited the inflammable mixture of gasoline vapor and air, and caused the beautiful, expensive car to burst instantly into flames.

A trained filling station operator, generally unobserved by the occupants of the car because it is done so casually, first touches the bare metal of the car with the end of the hose nozzle, before removing the cap of the fuel tank, in order to discharge harmlessly any electricity from the vehicle; and then he lifts the cap, after which, with immunity from fire hazard, he inserts the nozzle into the fill pipe of the tank.

Conclusions. Thus the author has found from these and other instances, where fires have resulted from the handling of gasoline en route to its destination, that ordinary precautions against fire hazards or recommended practices in its handling were either abandoned or ignored. Such flagrant violations of recognized safety practices are continually taxing industry with high economic tolls for costly physical damages as well as all too frequently resulting in irreparable personal injuries. State and municipal codes of regulations to govern the safe handling of gasoline and other highly inflammable products should be instituted, and they should be rigorously enforced for the welfare of all and the conservation of life and property.

MAN'S MULTIDIMENSIONAL ENVIRONMENT

By LAWRENCE K. FRANK

NEW YORK CITY

MAN finds himself in a series of environments to which he exhibits varying degrees of contingency. If we view human activity as occurring within a series of fields of which man's behavior may be regarded as a function, we may take one large step toward clarification of the present confusion and conflicts among students of human activity.

We may recognize initially therefore a number of environments, namely:

(a) The geographical environment of nature.

(b) The internal environment of the mammalian organism.

(c) The cultural environment of group life.

(d) The social environment of community living.

Each of these environments conditions the functional processes, the activities and the conduct of man, but with varying degrees of coerciveness.

THE GEOGRAPHICAL ENVIRONMENT

The basic geographical space, our natural environment in which all organisms exist, may be conceived as a series of ongoing processes and events—physical, chemical, biological—which occur in sequential patterns in accordance with the fundamental transformations of energy. More generally, we may speak of organisms existing in geographical space, subject to gravitation, radiation, barometric pressure, heat and cold, and all the many impacts to which they are exposed in their several life zones. Consideration of this geographical environment and its meaning for human activity has been directed largely to the more dramatic events that have brought either disaster or good fortune to man, with a consequent neglect of the continuous dependence of man upon the operation of these ongoing processes and events for his continued existence.

To say that we are waiting upon broadly conceived formulations of man's relationship to the natural environment is merely to recognize how greatly we need a new conception of the relation of man to the universe and realization that man is a part of nature, not outside nature, as our theological traditions have for so long insisted. As Alfred N. Whitehead has so cogently remarked: "It is a false dichotomy to think of nature *and* man. Mankind is that factor in nature which exhibits in its most intense form the plasticity of nature."[1]

The evidence is slowly accumulating in support of the conception of man as a cosmic resonator to a wide variety of energy transformations so that he is continuously absorbing, directly or indirectly, energy in different intensities as in sunshine, ultraviolet, electrical energy, infrared rays, etc. Moreover it is being shown that man is precariously dependent upon an adequate supply of the various minerals necessary for organic functioning and the various vitamins which he cannot manufacture for himself. How dependent man is for the constant supply of these substances is shown by the way in which his health and his sanity are threatened, if not lost, after any prolonged deprivation thereof.

To understand adequately man's relationship to the geographical environment of nature we must realize the many implications of man's mammalian ancestry, recalling the millions of years of evolu-

[1] *Cf.* Alfred N. Whitehead, "Adventures of Ideas." Macmillan, New York, 1933.

tionary development, both in the mammalian and in the pre-mammalian forms, through which he developed the capacity for existing in this geographical space and maintaining his amazingly complicated physiological processes, including reproduction, that are necessary for man's continued existence and perpetuation. Only recently have we begun to gain any understanding of these mammalian processes which are being revealed as the slow achievement of successive evolutionary forms culminating apparently in mammals and especially in man who has the widest range of existence of all mammals, from the arctic cold to tropical heat, from high altitudes to sea level and below. This then brings us to consideration of the next most important environment in which man exists.

The Internal Environment

Man's capacity for existing under such diverse and continually changing climatic conditions arises from his ability to maintain a relatively stable internal environment—an ability which, as indicated, was slowly evolved by his mammalian ancestors. As recent studies have shown, the various organ systems and glands of internal secretion interacting through the blood and the lymph and the nervous systems are engaged in continual readjustments for the maintenance of what W. B. Cannon has so well termed "homeostasis."[2] Through a series of amazingly delicate interacting adjustments, the mammalian organism is able to maintain its internal environment within fairly narrow limits of fluctuation, or to recover stabilty very quickly after it has been displaced through some external event or pronounced organic activity. Thus the mammalian organism is able to exist in a fluctuating, ever-changing environment, responding to the variations of heat, cold, barometric pressure, oxygen tension, as well as meeting the impact of traumatic events, of infections, and the like, and also carrying on in the mature organism the internal functional activities associated with reproduction and lactation.

Just because this capacity for maintaining a stable internal environment was "learned" through millions of years of evolutionary development, these processes take place ordinarily with little or no awareness on the part of man and with little or no conscious effort beyond that involved in seeking food and drink and in eliminations. It cannot be too strongly emphasized that these achievements of our mammalian ancestors have conferred upon us an amazing degree of freedom, not only to live all over the earth under the widest range of climatic conditions, but to carry on an extraordinary variety of sustained activities that are possible only because these basic organic processes are continually taking care of our organic requirements and needs.

Because we think of the environment as something outside or surrounding organism, it is necessary to this discussion to reemphasize the statement that man, as a mammalian organism, exists in the geographical environment *and* also in this internal environment. It may be said that man lives between the external and the internal environments so that their interaction is continually being mediated by him through internal readjustments or overt activities. At this point it may be appropriate to point out that man derives from his mammalian ancestry, but unlike all his predecessors he enjoys a unique status, in that as an organism he is relatively young and plastic, having escaped that differentiation and specialization of structure and

[2] W. B. Cannon, "The Wisdom of the Body." W. W. Norton and Co., New York, 1932. R. G. Hoskins, "The Tides of Life." W. W. Norton and Company, New York, 1933.

function which has marked the end of the road for all other species. Man is indeed unique, as Julian Huxley has recently emphasized,[3] since he has survived without paying the price of fixity and sacrifice of further developmental possibilities, exacted from all other organisms. It may also be desirable to emphasize that man, as pointed out years ago, has a prolonged infancy, much longer than any other species, during which he is engaged in further growth, development and maturation and therefore is capable of considerable learning. In addition, man also has a much longer adolescence than any other species, which also makes possible further learning and adaptation before he reaches the adult steady state and more or less fixed patterns of activity of the mature organism.

It is indeed astonishing to realize how little has been known about man, his evolutionary and hereditary background, his gestation, his growth, development and maturation. As we will have occasion to point out later, all of our traditional ideas, conceptions and beliefs about man are derived from the most extraordinary myths and fantasies which can no longer be accepted in the light of the growing knowledge of human development.

Many of those who are interested in studying man and trying to understand his activities have attempted to escape from these traditional mythologies by developing a rigorously biological conception of man. They have invoked the foregoing picture of man, the mammalian organism existing in the geographical world of nature, as acted upon by the ongoing processes and natural events and in turn reacting to these through his inherited mammalian capacities. These attempts to develop a more rigorous biological conception of man are highly commendable and are very much needed if we are to gain a better understanding of human activities. It must be obvious, however, that to stop with a formulation in terms of man as an organism reacting to the geographical environment is to give a picture that is fundamentally inadequate and incomplete, since nowhere do we find man, even among the so-called most primitive groups, living on a basis of organic functioning and biological impulse.

Man, as indicated earlier, is indeed unique because, unlike all other species, he has made his adaptations, not by organic specialization and bodily differentiation, but through ideas and the use of tools; indeed, what distinguishes man from his fellow mammals is the development of the cerebral cortex which has not only made possible what we call human social life, but apparently has made it necessary for man to develop a mode of existence other than that of simple organic functioning and impulsive behavior. While it has been customary to think of man as driven by fear to build up defenses against a threatening environment and natural enemies, it may be suggested that to a considerable extent man may have been compelled to develop what we call social life, and especially the arts, by sheer ennui and boredom, because, having a large brain, he could not be content merely to exist on an organic level. It may also be suggested that since man, as man, appeared relatively late he found various life zones more or less preempted by older species that had established themselves through their specialized structural and functional capacities and could maintain themselves therein more efficiently than could man, when he attempted to live on a purely biological level. Thus it seems probable that both through boredom and through the need for developing a mode of living that was compatible with his needs and capacities and the opportunities available to such a late arrival, man

[3] Julian Huxley, "Man Stands Alone." Harper, N. Y., 1941.

proceeded to develop in his early days what we call culture.

The Cultural Environment

The conception of human culture has not been very widely used or accepted except among anthropologists and the students of pre-history; therefore, it may be desirable to approach the discussion of the cultural environment by indicating what at this time may have been the probable origin of culture. Let us recall that from his earliest beginnings man has faced certain persistent tasks of life, namely:

1. To come to terms with nature in order to gain sustenance, to find security, and to achieve survival in a world both precarious and problematic.

2. To organize a group life so that individuals can live together and participate in the division of labor, which group living both necessitates and makes possible.

3. To transform organic functioning and impulsive behavior into the patterned conduct of group life and of human living as distinct from biological functioning.

Each species has worked out a way of life by learning to deal with certain selected aspects of the life zone in which it lives. Thus in the same life zone we find insects, reptiles, birds and mammals, finding sustenance, achieving survival, but each living in one of the many worlds which that same life zone provides for the selective awareness, specialized needs and the differentiated capacities of each species. These separate worlds may and frequently do conflict or interlock in the sense that we have predators, parasites and symbiotic species; but it is not unwarranted to speak of these diverse but coexistent worlds as being created out of the totality of nature by what each species responds to and what it ignores and disregards in that life zone. We might say that nature presents a different perspective to each species which attempts to live within the dimensions of the life zone revealed by its own specific phylogenetic history.

In much the same way we may conceive of man working out his human way of life by developing the specific perspective which he imputes to or imposes upon the geographical environment of nature in which he finds himself. Here we have to face one of the major difficulties in attempting to clarify this larger problem of man and his environment, since we are prone to adopt a more or less unidimensional or absolute picture in accordance with our whole rational, intellectual tradition. We must make a special effort, therefore, in order to be able to think in multidimensional terms which means that we must recognize that man, as a mammalian organism, *exists* in nature and reacts to the ongoing processes and events of what we call the "real or physical world," but at the same time he develops a highly specialized picture of that world in accordance with the basic conceptions and assumptions that he makes about the world and himself.[4] Thus he exists in the geographical environment of nature and responds thereto with his inherited mammalian capacities, but nevertheless he builds up a highly selective version of that world and responds thereto in the rigorously patterned functions and conduct prescribed by his culture.

Culture, therefore, might be described as the process by which man creates and maintains this peculiarly human world and group way of life, this cultural environment which he imposes upon the geographical and the internal environments, upon nature and himself, in accordance with the basic ideas and conceptions which he himself has developed. All over the world, therefore, we find different groups of people all belonging

[4] *Cf.* the writer's paper, "Science and Culture." The Scientific Monthly, Vol. L, No. 6, pp. 491–497. June, 1940.

to the same human species but with minor variations of color and size, existing as organisms in the same geographical world of nature, yet each group lives in a distinct cultural world of its own historical creation. Each of these different cultures may be interpreted as an answer proposed by man to the persistent life tasks which he has faced and these answers may be said to arise from the four basic assumptions or organizing conceptions of each culture, namely:

1. The nature of the universe; how it arose, or was created; how it operates; who or what makes things happen, and why.

2. Man's place in that universe; his origin, nature and destiny, his relation to the world; whether in nature or outside nature.

3. Man's relation to his group; who must be sacrificed for whom; the individual's rights, titles, obligations and interests.

4. Human nature and conduct; man's image of self and his motives; what he wants and what he should have; how he should be educated and socialized.

With these conceptions or assumptions man has attempted to order events, to organize experience, and to give meaning and significance to the environing world and to his own life. Whatever exists and happens will be viewed and interpreted in terms of these basic ideas, beliefs, and conceptions which are expressed in what we call the religion, the philosophy, the law and the art of each cultural group. They provide the only group sanctioned ways of believing, thinking, acting, feeling, and speaking, giving rise to the *eidos* and the *ethos* of each culture.[5]

The more we reflect upon the cultural environment the more amazing it becomes, because we see that under the coercion of his own historically developed culture man has rigorously limited himself to what he may, may not, and must do, often depriving himself of the rich opportunities offered by his life zone for meeting his needs and requirements as seen in the extraordinary variety of taboos and inviolabilities which he has established for his own observance. Moreover, we see man engaged in a bewildering array of rituals and ceremonies designed to deal with the environment as conceived by his culture, which, in the light of our growing knowledge of natural processes and events are often erroneous. No better example of this can be cited than the amazing variety of fertility rites that man all over the world has and still does practice, hoping by sympathetic magic or other practices to enhance or modify the fertility of birds and animals upon which he depends for sustenance and his own fecundity. What is perhaps the most remarkable aspect of the diverse cultural environments that have been developed all over the world is that man has been able to survive *despite* the misconceptions and erroneous assumptions he has made about nature and himself.

What we need to emphasize here is that this cultural environment is a highly developed series of possibilities, of compulsions and of prohibitions which very specifically define the geographical environment of nature, the internal environment and man's interactions therein. In any attempt to understand human activities full recognition must be given to this cultural environment since it is usually more coercive and restrictive than the geographical environment of nature and the internal environment of his own organism. Moreover, it must be evident that man cannot, except perhaps when psychotic or wholly lacking in intelligence, live on a biological basis of simple physiological functioning and organic impulse. Here we see why the well meant efforts of many scientists to

[5] *Cf.* Gregory Bateson, "Naven." Cambridge University Press, London, 1936. Esp. Chapters iii, viii, ix, xiv and xv.

foster a more objective and realistic view of human existence, however laudible their attacks on superstition and folklore, are inadequate and must be rejected since man cannot accept and live upon a purely objective basis. To be wholly objective means to deal with the environment only in terms of the processes, events and the biological functions of nature and to reject any patterns of conduct which involve aspirations, inhibitions, functional patterning, and the other aspects of human conduct as distinguished from organic behavior.

Moreover, culture, by the very demands it places upon man and the limitations it imposes upon his naive organic demands and functioning, frees him from the coercive control of hunger, sex and emotional outbreaks. If he did not learn to modify his internal environment by transforming hunger into appetite for the food favored by his group, eaten at the prescribed intervals, he would be driven incessantly to seek and appropriate available food and eat continuously like many other organisms. If also he did not build up some respect for the inviolability of things and persons—what we call private property and the sanctity of the person—he would be continually subject to invasion of his body and goods by others or driven to attack others. Moreover, if he did not develop the awareness and the rather rigidly patterned emotional expressions and repressions, as favored by his group, he would miss most of the richness and significance of life and be at the mercy of every emotional impulse in himself and others. Indeed, we must recognize that whatever we cherish and value in life derives from the cultural formulations that have given meaning and richness to nature and living, all of which would be lost or destroyed by a purely objective mode of acting and thinking.[6]

[6] *Cf.* the writer's paper, "Art and Living," *The American Magazine of Art*, May, 1932.

What culture does is to establish a selective version of the geographical environment and also a more or less rigidly controlled or restricted internal environment, so that both environments operate upon man to foster the kind of conduct and functional activity favored by the group traditions.

The necessity for recognizing the cultural environment and its coerciveness appears more clearly when we view the process by which this cultural environment is established. Unlike the geographical environment of nature and the organic patterns and functional activity of the internal environment, the cultural environment depends for its continuation and maintenance upon the process of culturation, that is, educating each generation of children in terms of the basic ideas and conceptions, the selective awareness, the sensibilities, the socially sanctioned ways of functioning, thinking, believing, speaking, acting and feeling. Only insofar as children learn to see the world, including other people and themselves, in terms of their cultural traditions, learn to observe the group sanctioned patterns of functioning, conduct and feeling, will a culture persist. Each child in all the different cultural groups throughout the world arrives on the scene as a more or less plastic organism who is rapidly molded into the patterns approved by the group so that the cultural environment in which he grows up becomes the only valid and acceptable way of seeing, thinking, acting and feeling. Indeed, this parochialism of cultures by which the individual learns what the group traditions teach and grows up to believe that that is the only valid way of looking at life, is one of the very curious aspects of human existence as expressed in intolerance and other forms of narrow-minded suspicion of all that is different.[7]

[7] *Cf.* Eliot D. Chapple and Carleton S. Coon, "Principles of Anthropology." Henry Holt and Company, New York, 1942.

We must continually remind ourselves that the cultural environment is a human creation which depends precariously upon the continuity of tradition, that is, upon inculcating these basic patterns of ideas in children. There is nothing in the natural biological environment which requires or necessitates any *specific* cultural pattern or social organization although, as indicated earlier, it seems clear that some form of culture is essential to man. Perhaps we might say that nature has been patient of the amazing variety of cultural formulations which we find all over the world.[8]

The coerciveness of the cultural environment upon man derives from the very process by which it is established, namely, the education of the young child, who, as he grows up and reacts to his internal environment and to the external world is continually supervised and admonished by his parents and other adults so that he is forced to accept what he is taught, at least to the extent of adopting the larger patterns of his culture as we will see later. However, even the most coercive teaching does not produce a uniform result since each individual will accept these teachings in his own idiomatic fashion.[9]

Undoubtedly the persistence of cultures, despite the anomolies and the almost unbelievable practices, has been due in large measure to the sanctions that have been invoked for maintaining the culture. Every culture apparently has a theory of origins which usually teaches that their particular culture is a superorganic, superhuman, if not supernatural, creation which may not be criticized or questioned. Thus we find that each group believes that its culture is a part of the cosmos and operates wholly above and beyond human direction and control. To criticize or to challenge these basic conceptions and beliefs is considered impious because the culture is believed to be the product of some supernatural revelation that has been given to man for his guidance. Thus, theology, philosophy, law and art reiterate and reenforce the basic cultural formulations and support the social life which provides,

The Social Environment

As pointed out earlier, the persistent life tasks which have faced man from the very beginning arise from the necessity of coming to terms with nature, of organizing some kind of group life and of imposing some patterns of conduct upon human activity. Here again we find that the social environment, like the cultural environment, may be regarded as a field of limited possibilities of human conduct, within the range of which the individual must carry on his life activities. We may gain a better understanding of this social environment if we will recall how the young child, beginning shortly after birth, is inducted into the use of these socially sanctioned patterns of conduct. The infant undergoes the process of socialization, as it has been called, wherein he is called upon to surrender much of his physiological autonomy and accept group sanctions, customs and patterns. He learns to adapt his physiology to the food and eating practices of the group, he accepts certain patterns for the control of eliminations, and he submits to certain patterning and regulation of his emotional reactions to others. Here we see how the culture supports the social life which in turn imposes upon the individual certain basic patterns of functional activity that are considered desirable, if not necessary, to the group life so that the infant soon accepts what the social life demands and permits as the appropriate way of living.

The young child also is inducted into

[8] See World Order and Cultural Diversity, *Free World*, June, 1942.

[9] *Cf.* the writer's paper, "Cultural Coercion and Individual Distortion," *Psychiatry*, Vol. 2, pp. 11–27, 1939.

the use of language and rapidly learns not only to respond to the verbalizations of others but to utilize those verbalizations for communication to others. As the study of comparative linguistics has shown, while there is a limited number of larger categories of languages, nevertheless there is an amazing variety of language systems, each of which is adapted to express the ideas and concepts that are supplied by the culture with a vocabulary that represents historically the development of the group life. The young individual is also taught to recognize the wide variety of symbols and their meanings, which involves the recognition of highly specialized meanings and significances that are imposed upon the common features of everyday life because they have received that conventionalized significance. As soon as the child has begun to become more or less oriented to life and capable of asking questions and understanding, he is taught the basic ideas and beliefs of his culture so that from his earliest days he learns to see and interpret the world around him according to his cultural prescriptions, and he is thereby progressively transformed into a participating member of his culture and of his society and learns to live in the cultural and the social environments provided by the group life.

As pointed out earlier, the major problem of group life is to transform the naive, impulsive behavior of individuals into patterned conduct so that they can live together, participate in the group life and, above all, can and will accept the requirements for social order. It is evident that if each individual is free to express his impulses and aggressive actions there can be little orderly social life and not much opportunity for any other activities than those observed among animals which spend most of their lives in hunting food and defending themselves from attack. Thus we find that each cultural group builds up an orderly social life by inculcating in the young the observance of the inviolability of objects, places and persons which we call private property and the sanctity of the person. This comes about through the process of prohibiting the naive, impulsive action of children toward objects and people, often by more or less severe punishment, until they can learn to tolerate exposure to biologically adequate stimuli without responding thereto. Thus we see how the prohibitions laid upon children by adults are transformed into self-administered inhibitions which prevent the child, even when beyond adult scrutiny, from approaching, taking or attacking. It may be suggested that the concept of inviolability is probably one of the basic aspects of all cultures and all societies since some observance of inviolability of objects and of persons, particularly those of the other sex, has been found in all groups thus far observed.[10]

The young child must learn not only to observe the inviolabilities described by his society but he must also learn to perform all the different actions which are deemed necessary and appropriate, such as those that are defined by the masculine and feminine roles and kinship relations, by the group sanctioned scheme of rank, caste, and class and similarly prescribed conduct. Thus the child grows up under the constant tuition of his parents and other adults to learn a repertory of conduct of what he must not do, and what he must and what he may do, and his status in the community is largely defined in terms of these prohibitions and compulsions. The whole scheme of property owning and control and the regulation of sexual activity and mating therefore is based upon these fundamental lessons in inviolabilities and compulsory activities.

[10] *Cf.* the writer's paper, "The Concept of Inviolability in Culture." *American Journal of Sociology*, Vol. xxxvi, No. 4, pp. 607–615, January, 1931.

Preparation for the social life starts with these fundamental lessons of inviolability and compulsion, but in order to provide for the orderly patterned relations between individuals the group life must provide more or less well-prescribed institutional practices and rituals, such as contract, barter and sale, courtship and marriage, property owning, litigation and the various political practices such as voting, negotiation, and the various activities associated with war and defense. It is these more or less stereotyped institutional practices which everyone must utilize in daily living that direct the conduct of each person to another who responds with the appropriate pattern. Thus the aggregate of patterned individual conduct gives rise to that appearance of order, regularity and uniformity which has been interpreted as the evidence of a social mechanism or system.

What we should observe here is that through these lessons the young individual is taught the various patterns of conduct through which he can carry on his life activities and he is given the aspirations and goals, the picture of a life career in terms of which he will direct his energies.

One of our most venerable beliefs is that our social life is a part of the cosmos, a sort of superhuman mechanism or organization, existing somewhere between earth and sky and operating through large scale forces like gravitation which we call "social forces." The belief in this so-called social organization is widely accepted by social theorists and social philosophers, deriving in large part from the historical fact that when the philosophers and political theorists and economists and later sociologists attempted to order events they took over the Newtonian conception and utilized it as a conceptual scheme for the discussion of social life and group activities. It must be evident, however, that what we call the social environment is essentially a historical development of man's own creation which he has imposed upon himself in the endeavor to achieve some form of social order and that its persistence depends wholly upon the perpetuation of these patterns from generation to generation.

It must be obvious that group life and what we call social organization are essentially aspirations, an attempt to create some form of social order which is never given, but must be achieved by patterning the naive and impulsive behavior of man into orderly and regular conduct. The observance of inviolabilities of things and of persons, and the performance of compulsory activities through the use of group sanctioned stereotyped rituals and institutional practices are essential for any large aggregate of individuals who live in close proximity and in the increasingly differentiated division of labor which modern technology makes essential. It may be asserted with all emphasis that some cultural formulations and some kind of organized group patterns of conduct are essential, but that the major question is "who shall be sacrificed for whom" or rather what sensibilities and values will govern the group life as thus established. With the emphasis upon technology and scientific knowledge it is necessary to assert vigorously that the quality of social life is governed primarily by sensibilities—of how we feel toward other persons, as we see when we examine what we call social progress wherein the development of new sensibilities have been the major factors in limiting or abolishing slavery and serfdom, child labor, and the other forms of human exploitation.

As soon as we recognize that social order is not given but must be achieved, by building into individuals the patterns of conduct, the aspirations, and the sensibilities which will govern the basic dimensions and quality of society, then we

will realize that the social scientist and the technologist can tell us how to proceed, but they cannot tell us what to strive for. This is essentially a task for the artist who can create and refine the sensibilities and the aspirations that will govern the group life. Above all the quality of the group life reflects and to a large extent expresses the personality-character structure of its members, since the individual, as an individual, while existing as an organism in the geographical world of nature and surviving through the operation of his internal environment, carrying on his life activities in the cultural and in the social environments of which he is a participating member, really *lives* in his private world.

Private World

To say that each individual really lives in a private world of his own may sound utterly absurd because we see others moving about in the common public world of our social life, using language, institutional practices, and the general patterns of social conduct and otherwise giving very compelling evidence that they are sharing the same world in which we live. We all do exist in the common world of geographical space as indicated earlier, we move about as organisms and interact with the geographical environment; indeed, one test body or instrument for recording this real world of geographical space is the human organism and its response to varying conditions of barometric pressure and temperature to say nothing of the response to gravity. Moreover, as we carry on our daily activities of buying, selling, negotiating, and otherwise participating in shared activities, we see clearly that we are participating in the public world of our traditional culture and our social life. Here is where it becomes necessary to invoke a multidimensional conception of the environment to enable us to grasp the conception of the individual human organism living in different environments for each of which there are highly appropriate data.

We may obtain a better understanding of this private world environment in which each individual lives if we will recall again the process by which the individual child is culturized and made a participating member of his society. Parents and teachers of the young all share a more or less common understanding of what the culture and the society prescribe and attempt to communicate these beliefs and patterns of conduct to the young, but each individual differs genetically and constitutionally and has had different life experiences, especially in the way he or she has developed an affective or emotional attitude toward life and toward this particular child who is being instructed. The lessons are supposed to be officially correct in accordance with tradition but are always warped and biased according to the parent or teacher's own personality make-up and emotional orientation. It happens, therefore, that the parent-teacher presents to the child what he believes to be the official socially sanctioned lesson but it is a distorted and frequently bizarre version of the correct lessons. Therefore, not only is the child presented with a variation of the official cultural and social lessons, but what is more important, he receives this teaching always with a bias and an emotional significance that is uniquely his own. Here we must pause to point out that the individual organism, especially man, faces each new situation with a definite set or organic state which he carries over from his previous experience. Thus learning is a cumulative process and what we call the past continues to operate in the present insofar as past experience has modified the organism in ways that persist into the present.[11] Thus each new lesson pre-

[11] *Cf.* the writer's paper, "Time Perspectives," *Journal of Social Philosophy*, Vol. 4, pp. 293–312, 1939.

sented to the child gains an emotional significance and is biased by what the child has experienced earlier. Moreover, insofar as the child faces an adult who is exercising authority over him which is kindly or more frequently severe if not brutal, he is reacting emotionally to his teacher.

To say, therefore, that the individual child, undergoing the process of being culturized and made a participating member of our society, learns a highly idiomatic and idiosyncratic version of what he is supposed to learn, is to recognize the basic process of human learning and to accept what our whole experience of life confirms, namely, that each individual sees the world about him, including other people, always in terms of the highly specific meaning and emotional import which they have for him alone. Thus, the notion advanced earlier that the individual really lives in a private world of his own is but a confirmation of our own experience and the beginning of real insight into human conduct. Another way of approach to this same situation is to recognize that each individual lives in his specific "life space,"[12] which becomes organized or structuralized in accordance with his own peculiar life experience and feeling and emotional attitudes. In a very real sense we may say that the individual, moving about in the common public world in which all organisms exist, creates this very idiomatic private world or life space in which every object, situation and person is given the highly specific and peculiar meaning with which he invests all his experience. What we call personality may be viewed as this dynamic process of organizing and interpreting experience and reacting affectively to the situations and relationships which we ourselves impose upon events and people according to our life experiences. The personality might be likened to a rubber stamp with which we go about stamping situations and people with the particular set patterns of our personality. Whatever life has meant to us, especially in the earlier years when we have been building up this personality process, becomes coercive upon us so that we continue to see and feel toward life always in terms of these early established set patterns.

[12] *Cf.* Kurt Lewin, "A Dynamic Theory of Personality." McGraw-Hill, 1935, N. Y. Also recent studies at the Iowa State University.

If we will reflect briefly on this situation our own life experience will confirm what we have said, because we realize how impossible it is for any one person to see life in the terms and with the meaning that each situation presents to another. Moreover, we know that even when a group of people are all in a small room listening to a person speak, each individual in that room will be seeing a different speaker and hearing a different speech, not what the speaker says but rather what each individual hears.

The individual personality has a highly developed selective awareness which picks out of the total situation that to which it will attend, and that which it will completely ignore. To a certain extent this personality process might be compared to a chemical valence, as we have learned to speak of the capacity of different substances to react chemically with others. Thus we know that if we apply a specific acid to all the different substances in a room it will react upon some and be unable to act upon others, and in each chemical reaction that takes place there will be produced a specific kind of salt, depending upon the kind of acid we employ. In much the same way the individual personality process will interact to certain situations and avoid all others and when it does react it will always contrive to produce the kind of situation which that personality process requires.

The beginning of an understanding insight of human conduct comes with the realization of these private worlds in

which we live and from which we can never escape. Only thus can we begin to understand the fears and compulsions, the anxieties, the hostilities, the prejudices and resentments, the enthusiasms and dislikes which each individual brings to life, and only thus can we begin to gain a sympathetic awareness of how certain individuals spend their whole lives in prolonged conflict or anxious concern over questions which, to an outside observer, appear to be utterly absurd and without substance. What we call the neurotic is essentially an individual whose private world is built upon some bizarre, if not fantastic, assumptions which he insists upon maintaining even though it may require all his energies and force him to renounce all other life activities. Indeed, the most astonishing aspect of human conduct is the way in which individuals dedicate their lives to utterly unreal but completely compelling beliefs and purposes that can be understood only insofar as we can sympathetically understand the private world that gives those beliefs and purposes their coercive meaning.[13] Nor can we understand the amazing irrationality of human conduct unless and until we can realize how much of our thinking and acting is dictated by the persistent, affective reactions that were built up in us in childhood which continue to dominate all the rest of our lives and make us constantly feel anxiety and guilt or resentment and hostility and force us to be dependently submissive or arrogantly dominating to others.

As we come to understand and accept this private world environment in which we really live we begin to see a little more clearly what human history means as we realize how individuals and groups have always been moved by the assumptions and beliefs of their culture and the coercive dominations of their private worlds regardless of how they differed from the so-called objective real world of nature. We may also begin to understand why the wholly rational arguments and programs that are offered man so seldom receive his recognition or acceptance. As we see in the more serious cases of mental disorders the individual must at all costs to himself and to society strive to maintain the private world in which he lives. Only that which is emotionally congenial and can be incorporated into the dimensions of this private world will be accepted by individuals and by groups. As we look back historically on our own culture and on the records of other cultures we see recurrent phases of extreme pressure to force the individual into developing a private world that is rigidly organized by outside authority or alternating periods when individual deviations have been not only tolerated, but encouraged. If the contemporary discussions of democracy with the emphasis upon the recognition of the integrity of the individual are to have any meaning, we must begin to translate that aspiration over into a program and a process that will attempt to foster the development of the individual private worlds that will be more sane and wholesome, that is, less conflicting and distorted by neurotic and emotional disturbances, oriented to the larger common purposes and goals through which alone a society can gain unity. Until an individual personality can live at peace with himself in his private world he cannot live at peace with his group life. For an orderly society we need individuals capable of orderly cooperative living, who can bear the burdens of freedom and sustain social order in and through their own personal conduct and feelings.[14]

III

We have inherited a series of ideas and beliefs about man and nature, many

[13] *Cf.* the writer's paper, "Freedom for the Personality," *Psychiatry*, Vol. 3, No. 3, August, 1940, pp. 341–349. Also "Projective Methods for Study of Personality." *Journal of Psychology*, 8, 389–413, 1939.

[14] Erich Fromm, "Escape from Freedom," Farrar and Rinehart, N. Y., 1941.

of which have become incredible in the light of new scientific knowledge and understandings and many of which have become intolerable to our more recently won insights and aspirations. If we accept this multidimensional conception of man's environment, we may clarify some of the present day confusions and conflicts, not only in public affairs but also in scientific discussions.

It is evident from even a hasty perusal of scientific literature that each scientific discipline has developed its instruments and techniques for research and is inclined to formulate or to reformulate every question it investigates in terms of the assumptions and concepts of that discipline. Thus the biologists are eager to translate all questions concerning man and his behavior into biological questions and insist that only such questions are scientific. It can be asserted that purely objective methods and data are essential to biological investigation but that man merely *exists* as an organism in geographical space. All his observable conduct and group relationships are cultural and social which are not objective, but are aspirations and ideals, like local distortions and aberrations of the geographical space that is bent or curved in the immediate neighborhood of the sun.

In similar fashion the physiologists and others who are concerned with man's functional processes, with the maintenance of his internal environment, are often emphatic in their assertions that only objective methods and data as found by their techniques are possible for the study of human behavior and conduct. Whatever can not be brought within the reach of these physiological methods they would ignore or rule out as irrelevant and worthless. Curiously enough this position has been recently undermined and rendered almost untenable by the cumulative evidence of how man's internal environment can be seriously and persistently disturbed not only by emotional reactions but by persistent affective disorders. Thus a man's heart rate or blood pressure may be enhanced by anxiety or hostility which differ from fear and rage, in that they are chronic tensions localized in one organic function while fear and rage are all over total organic reactions to some exigent or threatening situation. Even more significant is the demonstration that these persistent functional disturbances can often be reduced or even eliminated by treatment of the personality of the individual, especially by helping him to recall the often forgotten events which have been disturbing him.

What is of especial significance is that in the absence of an adequate biological stimulus-situation the individual reacts with an organic process wholly irrelevant to or incongruous with the actual situation in which he finds himself: his heart beats are accelerated as if frightened or under heavy load of exertion while seated in a room alone; his vascular system contracts, his respiration is accelerated or constricted, his skin blanches or is suffused with blood or exhibits local disturbances, and so on.[15]

Thus the realization of how persistent affective reactions, derived from prior experience, chiefly from childhood, can disturb physiological functions, has made the criterion of purely objective physiological data rather complicated if not impossible, since individuals and experimental animals are reacting affectively all the time.

Psychologists have also proposed their formulations and applied their methodologies to man and his conduct primarily in terms of their specific assumptions and dimensions. There are of course many different schools of psychological investi-

[15] *Cf.* H. Flanders Dunbar, "Emotions and Bodily Changes," Columbia University Press, New York, 1939, second edition. Bela Mittleman and Harold G. Wolff, "Emotions and Gastroduodenal Functions." Psychosom. Medicine, IV. 2. Jan. 1942, p. 5–61.

gation from the purely reflex study, similar in intent and scope to that of the physiologists, to the larger range of the social psychologists, the educational psychologists and others who are more concerned with man's conduct and feelings. What should be noted is that each of these schools emphasizes one or more aspects of human behavior or of man's reactions to these different environments in its methods of study and upon those limited data often erects a large edifice of theory concerning all of human conduct.

Social scientists are inclined to focus their attention upon the institutionally patterned conduct of social life as exhibited in buying and selling, of economic affairs and voting, etc., of political life or the varieties of deviations shown by delinquents, criminals, vagrants, and so on. It has been customary to assume, as indicated earlier, that there is a superhuman mechanism or organization which regulates economic, political and social life through the operation of large scale forces, acting at a distance. The study of human conduct and of group life in terms of this assumed mechanism or organization ignores the biological and cultural environments and the individual personal private world. What is especially to be noted is that the activities of individuals in an institutionally structured social environment are registered in a wide variety of records—prices, votes, wages, consumption, production, and so on. If these different data are reified into entities, forgetting that they record human activities, then we may create problems that can never be solved because artificial.

Likewise, among students of the human personality there is a disposition to focus upon the individual's internal environment and private world and neglect the social-cultural world in which that individual personality arose and now is living. Thus, some formulate the problem of human conduct largely in terms of biological instincts to which they attribute most, if not all, of human activities, minimizing or ignoring how culture operates to modify the so-called instinctive processes which in men are less coercive than in any other species.

It should be evident that we need a multi-dimensional conception and methodology for the study of human conduct, wherein all the disciplines may collaborate by helping to observe and, wherever possible, measure the many dimensions of man's environment and of his patterned conduct and feelings.

THE FAMILY LIFE OF CENTRAL AMERICAN WOODPECKERS

By Dr. ALEXANDER F. SKUTCH
SAN ISIDRO DEL GENERAL, COSTA RICA

FEW birds, it seems to me, lead such easy, comfortable lives as the woodpeckers. The specialization of bill, tongue, feet and internal structure which enables them to carve into fairly hard wood places at their disposal rich supplies of food quite inaccessible to all their bird-neighbors. But while they have the more deeply imbedded wood-boring grubs all to themselves, the majority of the woodpeckers remain sufficiently flexible in structure and mentality to take advantage of other sources of nourishment. They eat fruit, catch flying insects, and some even store acorns and dead insects for less bountiful seasons. By virtue of their energy, resourcefulness and forehandedness, they easily satisfy their appetites and enjoy much spare time for rest or play. In this they contrast sharply with such small insectivorous birds as warblers and gnatcatchers, which must devote most of their waking hours to the unending quest for food.

True addicts to the life of ease and luxury, they disdain to pass the night exposed to rain and wind, in the manner of the majority of birds, but as evening falls seek the snug bedchambers they have carved for themselves in dead trunks and branches, where they sleep warm and dry. Compared with most other kinds of birds, they as a rule go early to bed and get up late, for, like other creatures with comfortable beds, they are frequently reluctant to quit them. Their eggs and nestlings, placed in these same neatly carved cavities, generally at a good height, are less exposed to attack by snake and hawk and weasel than those of birds that nest in the open. Hence baby woodpeckers can afford to linger longer in the nest than the young of most small birds; for as a rule, the greater the nestlings' exposure to attack, the more precocious their dispersal. Young woodpeckers do not venture forth from their snug nursery until they can fly well and escape most of their enemies. Because of its relatively high reproductive efficiency, added to its adaptability, the woodpecker family has been highly successful in the struggle for existence, has evolved a great number of species, spread to most of the wooded regions of the earth, and even become established in certain areas practically devoid of native trees, such as the pampas of Argentina, where a species of flicker is at home.

To other birds as well as to man, woodpeckers are among the most useful citizens of the bird-world. They serve man by devouring wood-boring insects that destroy trees. The holes they carve into dead wood for dormitories and nest-cavities later become the sleeping and nesting places of a variety of other birds. Numerous kinds of wrens, flycatchers, cotingas, ovenbirds (Furnariidae), toucans, etc., raise their families in holes originally carved by woodpeckers, or else use them as dormitories. Birds such as the tityras of tropical America would have a hard time, indeed, finding sites for their nests, were it not for the activities of the woodpeckers. They and many other kinds of birds owe the woodpeckers a great debt of gratitude. Even the little hummingbirds, which sometimes sip the sweet sap or gather the insects that collect in the pits made in the bark of

trees by sapsuckers, benefit by the work of this industrious family.

Because they are so clever and industrious, and appear so happy, I have found particular pleasure in studying the habits of woodpeckers. What nature-lover has not been amused by the woodpecker who hides behind a trunk, peeking around the side from time to time to see whether he is still being watched? Who can fail to sympathize with the woodpecker peering through the round doorway of his snug bedchamber on a wet, chilly morning, gazing out upon the forbidding, rain-drenched earth, reluctant to forsake his dry retreat, yet very hungry for the breakfast he can find only out-of-doors—the very picture of indecision? Or what bird-watcher of feeling can fail to enter into the spirit of play of the idle, well-fed, ant-eating woodpeckers—as I have watched them in Guatemala—shifting little bits of acorn from one cranny to another, an occupation aimless yet doubtless amusing, and certainly very childlike. And who does not understand the delight of the flicker who chances to discover some particularly resonant surface on which to beat his tattoo?

The Central American woodpeckers range in size from the great, scarlet-crested ivory-bill, big as a crow, to the tiny, olive-brown piculet, one of the very smallest of birds, but every inch a woodpecker. In dress they vary from the harlequin attire of the ant-eating woodpecker—white, glossy black and red—to the almost uniform tawny-olive of the oleaginous woodpecker. In their family life, there is also great variation. According to their degree of sociability, those which I have had an opportunity to study in detail may be classified as follows:

I. A single pair attend the nest.

A. Individuals past the nestling stage always sleep singly; the male attends the nest by night; the fledglings are not led back to sleep in the nest after their departure. In this division belong:

Wagler's woodpecker (*Centurus subelegans*).
Hoffmann's woodpecker (*Centurus hoffmanni*).
Golden-fronted woodpecker (*Centurus aurifrons*).
Costa Rican woodpecker (*Chloronerpes rubiginosus*).
Pileated woodpecker (*Ceophlœus lineatus*).

Probably also these others of which my studies are still incomplete:

Guatemalan ivory-billed woodpecker (*Scapaneus guatemalensis*).
Oleaginous woodpecker (*Veniliornis oleaginus*).
Guatemalan flicker (*Colaptes mexicanoides*).

B. The mated pair sleep together throughout the year, and both pass the night in the nest while it contains eggs and young; the fledglings return to sleep in the nest with their parents, and may continue to do so until the approach of the subsequent breeding season. In this division belong:

Golden-naped woodpecker (*Tripsurus chrysauchen*).
Northern piculet (*Picumnus olivaceus*).

Although I did not succeed in following all stages of their life-history, from what I have seen of their habits, these woodpeckers agree with their congeners listed above:

Little Black woodpecker (*Tripsurus cruentatus*—eastern Ecuador and Peru).
Pucheran's woodpecker (*Tripsurus pucherani*).
Piculet (*Picumnus sp.*—eastern Ecuador).

II. More than two grown birds attend the nest.

In this division I know a single example: Ant-eating woodpecker (*Balanosphyra formicivora*).

As an example of the woodpeckers most solitary in their habits—in Central America, at least, the largest group by far—we shall take Wagler's woodpecker. A pair of these woodpeckers with red crowns and black-and-white-barred upper plumage dwelt in a new clearing at

the edge of the forest on the steep mountainside above the Río Buena Vista in southern Costa Rica. Here they were within a ten minutes' walk from my thatched cabin; and I followed their activities for nearly a year and a half, including two breeding seasons. Often I spent the last hour of the day in the old cornfield to watch them retire to rest, or arrived at the end of the night to see them begin their day. Like the majority of Central American woodpeckers, they remained mated through the year, permitting no others of their kind to establish themselves in their chosen territory. But they rarely paid any attention to the golden-naped and pileated woodpeckers which slept in the same clearing.

A number of fire-killed trees standing about the clearing furnished these Wagler's woodpeckers a choice of sites for their holes. They preferred to carve into such soft wood as the burío (*Heliocarpus*) and the guarumo (*Cecropia*). The male—usually the more domestic-minded of the pair among woodpeckers—was far more industrious than his mate in excavating cavities; hence he usually enjoyed the newer and sounder dormitory, while his less energetic mate was content to pass the night in such abandoned holes as she could find. They always slept apart, although sometimes their separate dormitories were in the same tree. Since the male's dormitory was the newer, it was natural that when the birds began to breed in February it should be chosen for the nest, in preference to the female's. Now the female, upon leaving her own dormitory in the morning, would come to visit her mate's, but would never enter until after his departure. After the eggs were laid, both sexes took turns at incubation during the day, sometimes sitting for an hour and a half at a stretch, dividing the daylight hours fairly evenly between them, and keeping the eggs almost constantly covered. But by night the male alone was in charge of the eggs, a natural outcome of their being laid in his own sleeping quarters.

The males of all the species listed in this group—with the possible exception of the oleaginous woodpecker, for which I have no observations on this point—take sole charge of the nest during the night. This is true also of the red-bellied woodpecker and the northern flicker of the United States. While in most species of birds the female incubates by night, there are a number of kinds of which the male is in charge. The male ani (cuckoo family) takes care of the nest during the night and by day sits turn and turn about with his mate. The male and female ringed kingfishers replace each other on the eggs only once in twenty-four hours, with the result that the male incubates on alternate nights. Many sea birds, including petrels, shearwaters and penguins, relieve each other on the eggs at intervals of several days, so that the male performs about as much night incubation as his mate. Finally, there are birds such as kiwis, tinamous and phalaropes of which the male incubates day and night with no help from a female.

When the eggs of the Wagler's woodpeckers hatched, both parents brought food to the nest, and took turns at brooding the naked new-born nestlings. Two distinct methods of feeding the nestlings are found in the woodpecker family. The parents, of some species, including the pileated and Costa Rican woodpeckers, bring food in the throat or crop and regurgitate it into the mouths of the nestlings. Other kinds, among them Wagler's woodpecker, the ant-eating woodpecker, the golden-naped woodpecker and the piculets, carry the food in their bills, where it is readily visible through field-glasses, and pass it directly to their offspring without regurgitation. For at least a month, the parent Wagler's woodpeckers continued to feed their

nestlings in their high hole in the dead guarumo tree. The father slept with them every night except the last. When the month-old youngsters at length departed their nursery, they had long been completely clothed with feathers, and could fly well.

After the departure of the young woodpeckers, the father returned to sleep in the nest-hole, and the mother continued to occupy her own dormitory in a neighboring tree. While the parents slept in their snug chambers, no provision at all was made for the comfort of the fledglings, which were obliged to sleep clinging to exposed trunks or branches until they managed to find unoccupied cavities for themselves. A few days after quitting the nest, young Wagler's woodpeckers begin to seek sleeping holes as night approaches; but since they exercise little foresight and receive no guidance from their parents, a week or more may pass before they are finally accommodated. When one of the fledglings attemped to enter the hole with its father, it was repulsed with pecks; and once when the youngster stole a march on its father and entered the dormitory first, it was rudely evicted as soon as the parent arrived. At an early age, the solitary disposition of these woodpeckers began to manifest itself in the mother's antagonism to the youngsters, and of these toward each other. Yet the parents continued to feed the young woodpeckers until they became self-supporting, when they were driven from the parental domain to shift for themselves.

Among the golden-naped woodpeckers, a far more friendly attitude prevails between all the members of the family. These beautiful little birds, neighbors of the Wagler's woodpeckers in the great forests of southern Costa Rica, will serve as an example of the more sociable woodpeckers of our second group (I B). For four years I have found pleasure in watching these amiable birds, and have followed the course of events at a number of nests. The mated pair sleep in the same lofty hole throughout the year, except possibly at moving time, when they change from the old hole to the new. Months before the advent of the nesting season, which begins in March or April, the male may work desultorily at carving out a new hole, not far from the old in which he sleeps with his mate and—if he has already raised a family—their full-grown children of the year. Usually he chisels at the new cavity for a short while before retiring in the evening; and at first the undertaking advances very slowly. But as the date of egg-laying approaches, he works more constantly, and in the morning; and now his mate takes a share in the task. If the hole is lost shortly before or during the breeding season, by the falling of the dead tree; or if a pair of mild-mannered but persistent tityras take it from these equally mild-mannered woodpeckers, both sexes labor diligently, turn and turn about, to carve out a new one. I might add here that when a new cavity is needed promptly during the nesting season, male and female of all species of woodpeckers—so far as my observations go—fall to with a will to prepare it. But the male is as a rule the more domestic-minded of the pair, and devotes himself to home-making at seasons when his mate sees no necessity to trouble herself about such matters.

As the golden-napes' new hole nears completion, one of the pair may sleep in it, while the other continues to use the old dormitory until the new one is big enough to hold both birds with comfort. This moving-period of a few nights' duration is the only time in the whole year when mated golden-napes sleep apart—barring temporary arrangements made necessary by the accidental loss of dormitories. This is the time also when any young birds who have remained with the parents since their last year's nesting

go off to shift for themselves—it is an unsettled period when each evening the woodpeckers behave in a different fashion. But as soon as the new hole is completed, male and female sleep together in it, and continue to do so during the whole period of incubation and of raising the nestlings, and for many months thereafter if nothing goes amiss. During the day, they incubate turn and turn about, in the manner of all the other woodpeckers I have watched. It is of interest that the member of the pair arriving to take its turn on the eggs often enters the nest before the departure of its mate; and the two may remain in the hole together for a few minutes before the one relieved of duty goes off to hunt food. The same is true of the piculets, whose life-history closely parallels that of the golden-napes. But in the less sociable woodpeckers of the group exemplified by Wagler's woodpecker, it is indeed rare to witness one bird enter the nest before the mate has departed; and on the few occasions when I have chanced to see this unusual procedure, the impatient new arrival has popped out of the doorway so promptly that I fancy it must have received a peck from the irate partner within.

Fledgling golden-napes quit the nest at the age of about 34 days, when they fly very well. In the evening, the newly emerged youngsters are shown back to the nest by one of the parents, or at times appear to seek it quite spontaneously. Rarely the fledglings are brought back to the hole by a special call of the parents. They may be fed in the nest after their return to it, just as though they were nestlings which had never been flying about in the open air—but this does not occur with all families. The capacious cavity is always kept clean by the parents, which carefully remove all waste matter in their bills. The young birds, and sometimes the adults, too, may take shelter in it during the heavy afternoon showers of May and June. For many months it remains the nightly sleeping place of the entire family, which dwell together in harmony until the approach of the following breeding season sends the young birds off to set up housekeeping for themselves.

In the eastern foothills of the Andes in Ecuador and Peru and on the western side of the great Amazonian plain, the most conspicuous woodpecker is a small, vociferous species clad largely in black, with a rich crimson patch in the center of the belly. I was not fortunate enough to find this little black woodpecker nesting at the time of my visits to this region; but at widely scattered points in Peru and Ecuador I saw from two to five grown birds retire at nightfall into the same hole. I believe that their nesting habits, when studied, will be found to agree closely with those of their near relations, the golden-napes. Recently I watched a pair of Pucheran's woodpeckers, a third species of the same genus. When I first found them, male and female slept together in the same hole, in which evidently they were preparing to nest. But they abandoned it when a tityra began to fill it with leaves, and started a new hole in the lower part of the same barkless trunk. When finally they began to incubate, the male took care of the eggs during the night, while his mate slept in another hole a yard away. I believe they slept apart because the nest-cavity was too small to accommodate both with comfort, as a result of the difficulty the birds experienced in excavating the hard wood. This observation suggested the answer to a question which had long been in my mind with reference to the golden-naped woodpeckers: Which member of the pair actually warms the eggs during the night? It is impossible to peep into their high holes while darkness covers the earth; but from the behavior of their close relations, the Pucheran's woodpeckers, I think it highly probable that

the male, as with most other woodpeckers, actually covers the eggs, while his mate sleeps clinging to the wall beside him.

Most sociable of all the woodpeckers of whose habits I know anything from personal observation or reading are the jolly ant-eating woodpeckers, so oddly attired in their harlequin costume. Acorn-eating woodpeckers would be a far more appropriate name for them. Doubtless, like many members of the family, they eat a certain number of ants, but acorns are their specialty. Their distribution is closely linked with that of oak trees. In Central America they are birds of the highlands; and both the upper and lower altitudinal limits of their range correspond with those of the genus *Quercus*. They store many acorns against the season of scarcity, in the northern part of their vast range in little cavities specially carved to receive each a single acorn fitting snugly; but in Central America they appear never to carve these special holes, being content to tuck away whole or fragmented acorns in such chinks and crannies as they can find already at hand in the trees.

Ant-eating woodpeckers are usually found in happy, loquacious flocks, containing at times half a dozen birds. Since they are as a rule scattered among the trees, it is difficult to determine the exact number in the flock. At night, the members of the flock sleep together in a cavity they have made, or at times divide up between neighboring dormitories, a few in this and a few in that. Five is the greatest number I have found sleeping in a single hole.

During the breeding season, a whole flock attends a single nest. At one lofty nest I watched in southern Costa Rica, four males and one female were all taking turns at incubating the eggs. With so many incubating, they shifted about very frequently. Seventeen minutes was the longest uninterrupted session I recorded in nearly twelve hours of neck-straining watching. This is of course an unusually short period for a woodpecker, for with other species sessions of under twenty minutes are rare; and many sit continuously for an hour or more, even by day. At night, the nest with five attendants was occupied by a single woodpecker—whether the female or one of the four males I could not determine, because of the height and the dim light that prevailed when it retired in the late evening and emerged in the early morning. The other four attendants of the nest went off together in the waning light, doubtless all to sleep in the same hole.

Was this a case of polyandry—very rare among birds—or did the nest belong to a single pair assisted by three unmated males? In Guatemala, some years earlier, I had studied nests of the black-eared bush-tits (*Psaltriparus melanotis*) at which the mated pair were helped in the care of the nestlings by males which had been unable to find mates, because of the great numerical predominance of their own sex. At another ant-eating woodpeckers' nest that I found about the same time, at least two males and two females were bringing food to well-grown nestlings. Possibly there were more attendants that I failed to distinguish. This combination suggested communal nesting by several pairs, such as is found among anis (*Crotophaga*); but here again it was not impossible that a single mated pair was assisted in the care of the nest by unmated birds of both sexes. A count of eggs in a number of nests would help elucidate the exact nature of the association existing between the several individuals that attend each nest. But unfortunately all the nests of the ant-eating woodpecker that I have seen were very high in dead trees unsafe to climb. Nor does the information presented in

Dr. Ritter's book on the Californian race of the ant-eating woodpecker bring us much nearer to a solution of the problem.

But assuming that we are dealing with a case of unmated, sexually immature birds assisting at a subsequent nesting of their parents, it is easy to see how such a situation could arise from that which prevails among golden-naped woodpeckers and piculets. If the young of these species would delay their breeding until their third year—as happens in many species of birds—and remain with their parents just a few months longer than they actually do, they would probably help them attend their younger brothers and sisters, in the manner of birds so diverse as moorhens, wrens, jays and bluebirds. In eastern Ecuador, I found a nest of a still unidentified species of piculet, in which one male and two females slept every night. Since the full set consisted of only two eggs, it is improbable that more than one of the females had laid. I believe that the second female occupant of the nest was a daughter of the first, raised at her previous nesting. I had high hope of seeing both females as well as the male bring food to the nestlings when they hatched; but unhappily some mishap befell this nest during a long-continued rainstorm, and I never succeeded in finding another of the same kind.

PRECIPITATION VARIATION IN THE UNITED STATES

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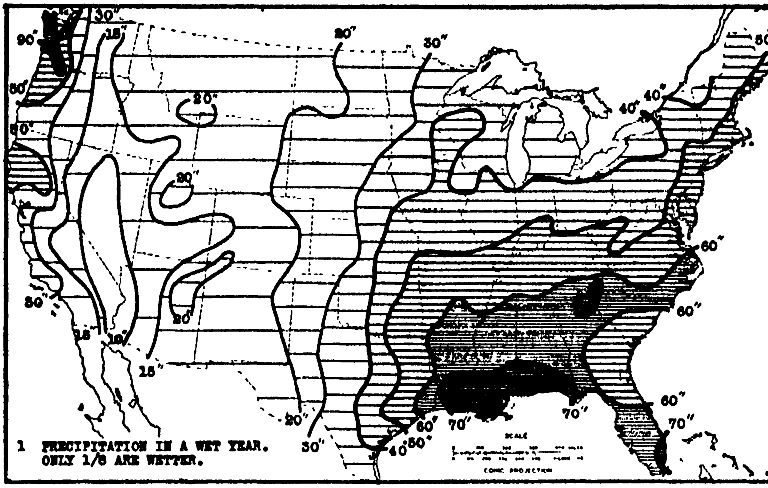
THERE are within the United States large variations in precipitation from year to year. The accompanying maps are for especially wet and dry years, summer and winters.[1]

Map 1 shows the precipitation totals for a wet year, the average of the wettest 10 out of 40 years—hence only one eighth of the years are wetter. In such a rainy year, only about a fourth of the West receives less than 15 inches of precipitation, while more than half of the East receives more than 50 inches. Three sizable eastern areas receive 70 inches or more, two of which include small areas receiving 80 inches. The rainiest part of the southern Appalachian Mountains receives 100 inches; one western Washington area receives 120 inches.

During the driest one eighth of the years (Map 2), considerably more than half of the country receives less than 15 inches of precipitation and about an eighth receives less than 5 inches. In such a year, no part of the East receives as much as 50 inches, except a small area in the southern Appalachians; in the West only a few stations receive more than 40 inches. This map shows that in such a dry year Washington, D. C., for example, receives about 33 inches, in contrast with about 50 inches in a wet year. It receives in a dry year no more precipitation than central Kansas receives in a rainy year.

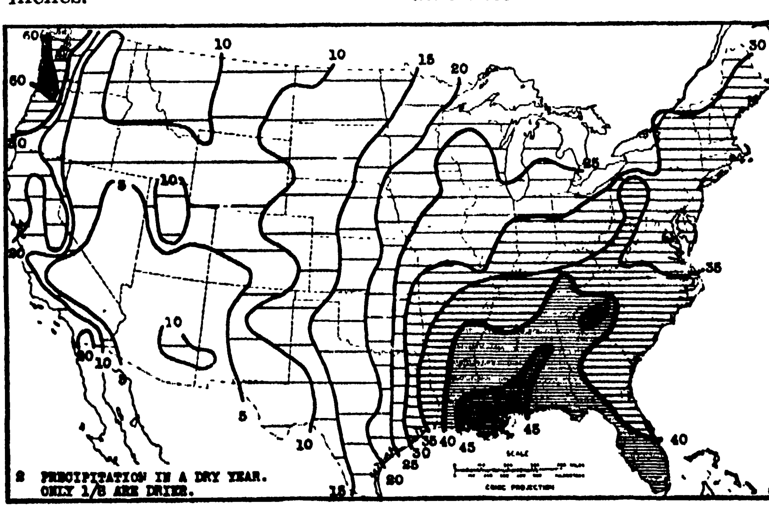
[1] Maps 1–4 are shaded redrawings of maps in the 1941 Yearbook of the United States Department of Agriculture, "Climate and Man." The maps redrawn were by J. B. Kincer, of the U. S. Weather Bureau, and are based on the records for 40 years (1899–1938) from about 5,000 stations. Maps 5 and 6 are original compilations from the maps of wet and dry years of 1900–1939 of C. W. Thornthwaite's "Atlas of Climatic Types 1900–1939," issued by the U. S. Soil Conservation Service early in 1942. Maps 7 and 8 are shaded redrawings of two Atlas maps. The Atlas is based on the records gathered by the Weather Bureau at about 3,000 scattered stations.

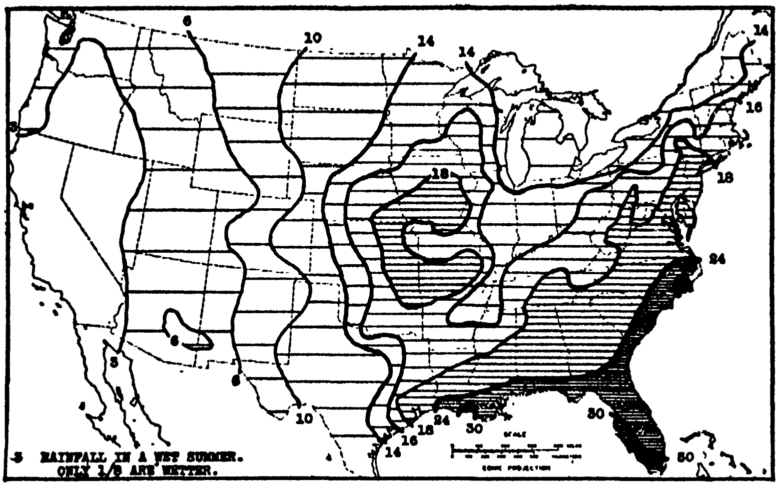


A comparison of Maps 1 and 2 shows that in the wetter parts of the country about 50 per cent. more rain is received in a relatively wet year than in a relatively dry one. In the central part of the country, the range between such years is about 100 per cent.; in the more arid section, a relatively wet year receives about three times as much as a relatively dry one. The range between the wettest and the driest individual years of record is much greater than threefold in arid regions: sometimes in an exceptionally dry year almost no rain falls, but in an exceptionally wet year 10 or 15 inches.

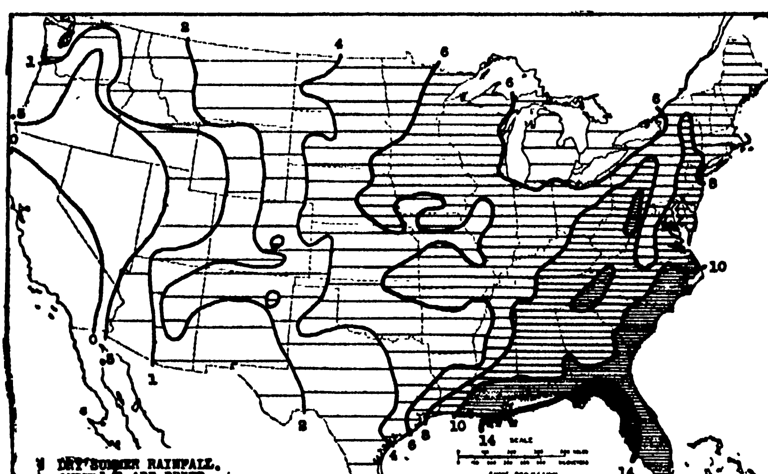
As the precipitation during the summer months is especially important for agriculture, Maps 3 and 4, showing dry and wet summers, are of special interest. The precipitation shown is the average of the 10 wettest or driest summers of the 40 years studied, hence only one eighth of the summers receive less than or more than the totals here shown.

In a relatively wet summer (Map 3) a southeastern coastal zone receives more than 24 inches of rain, and three areas therein receive 30 inches. A sizable central area receives from 18 to 24 inches, western Kansas receives about 14 inches and eastern Montana 10 inches.





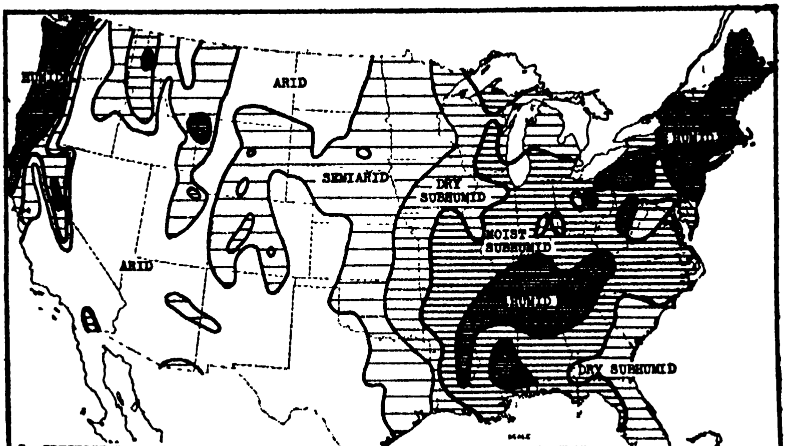
3 RAINFALL IN A WET SUMMER. ONLY 1/8 ARE WETTER.



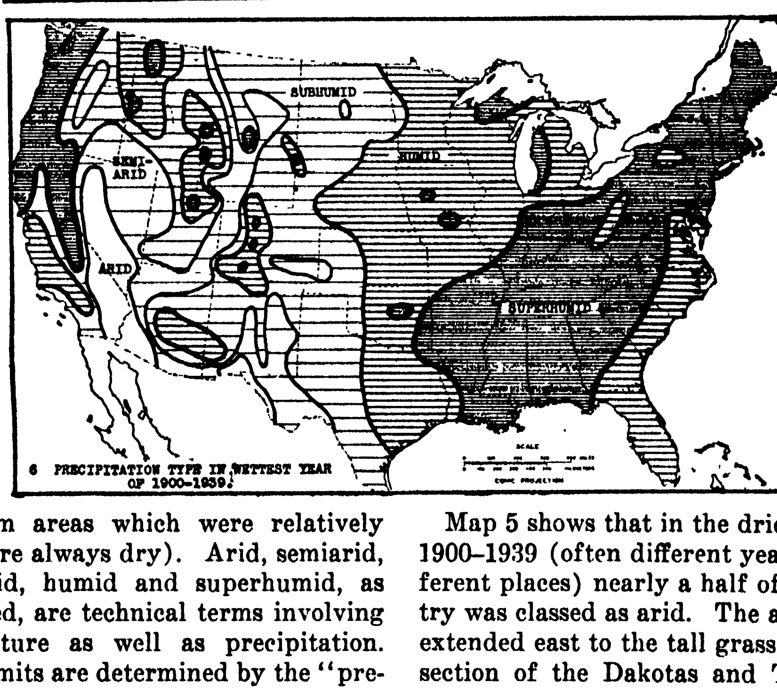
4 DRY SUMMER RAINFALL. ONLY 1/8 ARE DRIER.

Map 4, of the average rainfall of a rather dry summer, shows a sharp contrast to the previous map. During such a dry summer, western Kansas receives less than 4 inches in the 3 months and much of the South receives little, if any, more than 8 inches, or only about one third that received in the wettest one eighth of the years. Map 4 shows that a large western area receives during such a dry summer less than an inch of rain, most of California none at all. (In the wettest one eighth of the summers, all of California receives at least half an inch.)

It would be interesting to have maximum and minimum precipitation maps corresponding with those in the first article of this series, which showed the highest and lowest temperatures recorded in 40 years. Since such maps are not available, Maps 5 and 6 have been prepared by combining parts of many maps of Thornthwaite's Atlas. Map 5 shows the total or maximum area which was arid, semiarid or dry subhumid at least once in the years 1900–1939. Thus, conversely, it shows the smallest extent of humid, superhumid and moist subhumid areas in any year. Map 6 shows the maximum area which was superhumid, humid or moist subhumid at least once, and, conversely, the



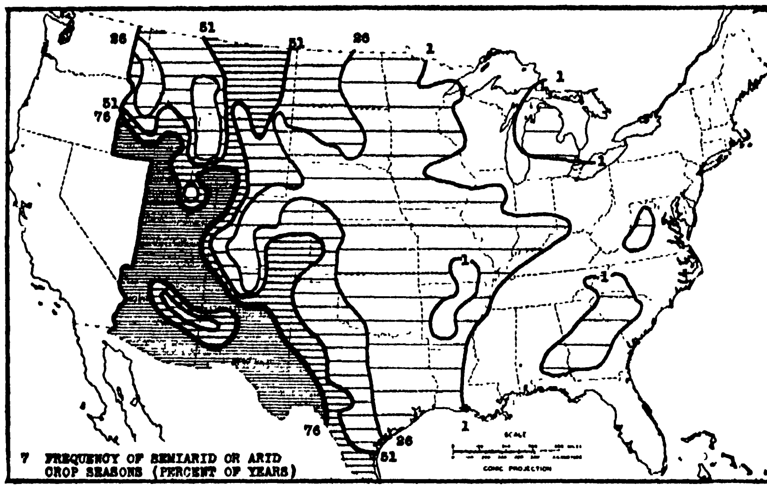
5 PRECIPITATION TYPE IN DRIEST YEAR OF 1900-1939.



6 PRECIPITATION TYPE IN WETTEST YEAR OF 1900-1939.

minimum areas which were relatively dry (were always dry). Arid, semiarid, subhumid, humid and superhumid, as here used, are technical terms involving temperature as well as precipitation. Their limits are determined by the "precipitation-effectiveness-index," which is laboriously calculated. Roughly, arid extends to about 12 inches of annual precipitation in the warmer part of the country, but to about 7 inches in the cooler part. Superhumid includes annual precipitation totals greater than about 65 inches in the warmer regions, and greater than about 50 inches in the cooler regions.

Map 5 shows that in the driest year of 1900–1939 (often different years for different places) nearly a half of the country was classed as arid. The arid region extended east to the tall grass or prairie section of the Dakotas and Texas, but did not include all the short-grass part of Wyoming and Colorado, which was semiarid in the driest year of the forty. The semiarid zone extended once as far east as the western edge of Wisconsin and Louisiana. Much of Michigan, Iowa and Florida were dry subhumid in the driest year of the forty. Most of the rest of the East was moist subhumid, instead of humid, while the truly humid sections



7 FREQUENCY OF SEMIARID OR ARID CROP SEASONS (PERCENT OF YEARS)

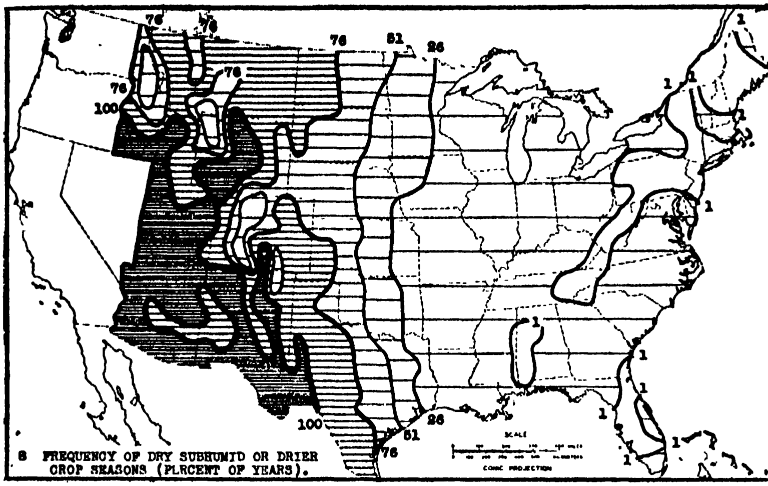
included only most of the Northeast, a part of the South and the North Pacific Coast.

Map 6, of the wettest year of 1900–1939 (different years in different places), shows that in an occasional year little of the West is arid, according to the definition here used; while more than half of the East and a large northwestern area are superhumid and the rest of the East is humid. In such a wet year, about half of the West is subhumid, rather than semiarid or arid, as it normally is.

The maps of each of the forty years 1900–1939 and of each of the crop seasons reveal that the variations from year to year often are large. For example, about twice as large an area was humid in 1904 as in 1934 and more than ten times as large an area was arid in the latter year as in the former. For the crop-growing season of 1936, the main agricultural region (east of the Great Plains) contained arid areas totalling about 100,000 square miles, and semiarid areas totalling fully 400,000 square miles, whereas normally none of the East is either arid or semiarid. In the 1936 crop-season, dry subhumid or semiarid types occupied about half of the eastern half of the country, but in 1938 occupied almost none of it.

The frequency of the occurrence of the various climatic types during the crop-growing season (here defined as March through August) is shown in Maps 7 and 8. Map 7 shows that semiarid or arid crop seasons occur in less than one per cent. of the years, if ever, in most of the East, but occur in approximately one fourth of the years about midway between the Atlantic and Pacific. In much of the West, more than three fourths of the crop-seasons are semiarid or arid. (The Atlas maps of the crop-seasons omit the Pacific States, but most of this area is also arid or semiarid during the summer months, as is seen by Maps 2 and 4 of the preceding article of this series, that on average precipitation in the United States.)

Dry subhumid crop-seasons are much more frequent in the East than are semiarid ones. Map 8 shows that only about an eighth of the East rarely has such a season. In the middle of the country from east to west, dry subhumid or semiarid crop-seasons occur in about half of the years. Almost all the crop-seasons in a large western area (including most



8 FREQUENCY OF DRY SUBHUMID OR DRIER CROP SEASONS (PERCENT OF YEARS).

of the Pacific States) are dry subhumid, semiarid or arid.

These 8 maps show rather clearly that the variation in precipitation from time to time is great. The reasons for the irregularity are not yet adequately known. Important influences are variations in the frequency, intensity, rate of movement and size of cyclonic disturbances. These Lows and Highs vary partly as a result of changes in pressure and temperature in distant places. Tropical cyclones migrating into midlatitudes sometimes have profound influences[2] Solar changes affect the atmosphere in complicated ways.[2] Although it is not yet feasible to explain the causes for the regional variations shown in these maps, an essential first step towards the solution of such problems is to have the facts to be explained clearly set forth. These maps are a step in that direction. They also afford some basis for "reasonable expectation," and hence permit a wiser planning.

[2] S. S. Visher, "Effects of Tropical Cyclones upon the Weather of Midlatitudes," *Geog. Rev.*, XV: 106–114, 1925; "Frequencies of Tropical Cyclones," especially those of minor intensity; *Monthly Weather Rev.*, 58: 62–69, 1930; "Climatic Changes, Their Nature and Their Causes," Yale University Press, 1922 (with E. Huntington).

FACTORS IN AGING

By Dr. E. V. COWDRY

PROFESSOR OF ANATOMY, WASHINGTON UNIVERSITY SCHOOL OF MEDICINE; DIRECTOR OF RESEARCH, THE BARNARD FREE SKIN AND CANCER HOSPITAL

THE wise physician, as well as anyone who would understand his fellows, will bear one fact in mind. It is that as the years pass the body undergoes an almost complete metamorphosis. Though made in the same pattern, it becomes constructed differently, functions differently and is directed by a mind which changes more than is usually recognized. His success will depend upon his knowledge of this change and his ability to be guided thereby. Only to sketch some of the underlying factors in rough outline is attempted here.

As in the period of usefulness of a motor car many parts have to be replaced, so also in the body there is much replacement. In both this is to compensate for wear and tear and it is naturally greater for some parts than for others. But in the motor a complete new part is fitted into the place of the old one, whereas in the body the replacement is better managed. New vital units or cells continually take the place of those worn out so that the efficiency of the part is not allowed to run down before replacement is effected.

The outer skin now covering our bodies is not the same sheet of cells that was interposed between us and our external environment several months ago though it is built in the same style. The cells lost from the surface have been replaced by others produced by cell division in a deeper layer or layers. Much the same holds for the inner walls of the respiratory, alimentary and urinogenital tracts and for many other tissues.

It is important to displace conjecture by facts in regard to these turn overs. We would like to know, for instance, the percentage of total body cells which are new in a man of thirty, that is to say which he did not possess at twenty-nine and the change in this gross turn over with each succeeding year. Some kinds of cells are evidently replaced thousands of times in the human life span, others hundreds of times and still others not at all. Until all the replacement cells can be classified in sequence from the highest to the lowest rate of turn over, ignorance will persist relative to a fundamental biological phenomenon. Some of these replacements lag and fail with advancing years, while others continue unto death with little or no depreciation.

But many cells are not replaceable. In this category we first think of nerve cells because no new nerve cells are formed after about one year of age. A conservative calculation indicates that their lives are approximately 2,190 times as long as those of the leukocytes that combat bacterial invaders, and in some cases very much more. Heart muscle cells, having lost their power of multiplication early, are also very long lived and are usually listed as non-replaceable. Voluntary muscle cells, certain cells of the retina and several others come in this group. But the percentage of total body cells that are not replaceable is not known.

A motor car is so constructed that all of its parts will stand greater strains than those expected. In other words a factor of safety, differing for each part, is observed. In the body Nature provides surpluses of cells both replaceable and non-replaceable. Data are almost

entirely lacking as to the size of these surpluses and their fate as old age creeps on. There is evidence of progressive decrease in the number of certain types of nerve and muscle cells. Decreases in taste buds and olfactory fibers have been reported. It is possible that the progressive depletion of such reserves may be an important and generally operative factor in aging. Evidence is not so wide-spread of depreciation in the quality of cells; but the long lived ones, which are not replaceable, frequently accumulate pigments, lipoids and various other relatively inactive materials which suggests a diminution in functional vigor.

Aging is not restricted to the living components of the body. Inanimate parts, which by contrast do not consume oxygen, or in simpler terms which do not breathe, also change with time. They include dental enamel, various fibrous structures and fluids—in fact all of the noncellular constituents plus the dead cells, *i.e.*, red cells in the circulating blood. Again quantitative data are conspicuous by their absence. It is not known, for instance, to begin with, what fraction of the body is dead. It must, however, be a large part, possibly as much as half. Does the fraction increase with age is another question that we can not answer. While we are in life we are in death is a true saying, for every part of the body in contact with the external environment is coated with dead cells and the whole can survive only through maintenance in adequate amount in the proper condition of the dead materials within it. Here there is also a surplus.

Dental enamel, once formed on permanent teeth, is never replaced. It is the hardest substance produced by the cells of the body. When dry it will strike sparks with steel like a flint. Kept in condition by the fluids of the mouth it is well suited to continued use through the years. As enamel deteriorates, or is lost, the whole organism suffers a severe handicap. Aging may then be hastened by inadequate chewing and the resultant faulty nutrition.

White connective tissue fibers, which possess great tensile strength and hold the tissues together, change with time. Though new white fibers can be formed as long as life lasts, replacement is inadequate because the old fibers are not removed in an orderly way, like dead cells, but tend to remain and clog the vital machinery. This progressive fibrosis in old age has often been mentioned. But the total increase in volume of the fibers has never been measured. In common with most of the other factors mentioned there are organ and tissue differentials. In some the increase is considerable, in others barely noticeable. Why this is the case is not clear.

Results of aging of the yellow, elastic connective tissue fibers are more tragic. These constitute the vital rubber of the body. Upon them depends the elasticity of the blood vessels, the urinary bladder, the skin and many tubular and other structures. They age by a colloidal change like automobile tires. New elastic fibers can be and are developed in a kind of furtive way even in very advanced years, but again the mechanism of replacement is altogether inappropriate. The old ones, having partly or wholly lost their elasticity and to some extent their architectural arrangement, clutter up the tissues and the new ones do not properly take their place. Again the change takes place in different volumes and at different rates in different localities.

Another factor in the aging of nonliving components is a shift in distribution of mineral salts, particularly of calcium. These tend to leave the bones and to accumulate in other tissues including the walls of blood vessels as x-ray photographs of aged persons so often show. Consequently the bones which should be

strong and rigid are weakened, and the vessel walls which should be elastic and yielding are stiffened.

These sweeping changes in living and nonliving bodily constituents are obviously linked with alterations in functional performance. Limiting our sketch, as before, to the broad outlines and excluding highly specialized and localized activities, mention must first be made of decrease in adaptability for this is manifested sooner or later in all parts of the body that have been adequately studied. The nervous system adjusts itself less well to change, the cardiovascular system responds less effectively to unusual demands, old people suffer more from sudden alterations in temperature and so on almost without end. Decreases in perception and responsiveness occur all along the line.

That regulation also begins to break down is best observed in the most visible part of the body, the skin. Here are noticed small areas of increased pigment and sometimes of loss of pigment, of increase in cells and perhaps of decrease in cells, of the production of a few large hairs (in nostrils and eyebrows) and of the loss of many hairs. Such changes, innocent in themselves, are nevertheless signs of the times. They betray an increasing imbalance, a curious indecision, a less regulated behavior, which is probably not lacking in the deep-lying, hidden tissues. How much this teetering has to do with the cancerous transformation by which cells shake off community control, and live for themselves alone, we do not know. That it is not a factor in the production of all cancers is clear, because some types characteristically appear in youth and after a certain age is passed the incidence of certain cancers is not increased.

But aging is not simply a case of the wearing out of the body in the continual adjustment to alterations in the external and internal environments which shapes individual life. Hereditary factors are important. According to the embryologist, Streeter, "Whether the infant survives its first year depends in considerable part on the original quality of the egg. If they withstand the usual wear and tear of life until between fifty and sixty years they conform to the actuary's expectation of life, at birth—and to the embryologist's expectation of the performance of an egg of average quality. It is only the extraordinarily good egg that is still going strong at 80 years, and we see him (or her) do this in the absence of any exquisite hygienic regime or experimental favor." He goes on to explain that "The egg as a whole, of course, consists of a multitude of elements and it is the sum and integration of these that determines its fate." Some of its parts may lead to hardy, long lived tissues and others to tissues handicapped at the start. Thus, mortality tables become intelligible "if one accepts the point of view that there is an egg-determined life span and an egg-determined vitality of individual organs." Streeter obviously had reference to the egg after entrance of the sperm. The male contribution to heredity is not to be ignored.

Perhaps the principal factor productive of premature aging and death of individuals, hereditarily equipped for longer usefulness, is continuance of unabated nervous drive. Not appreciating the fact of this bodily metamorphosis, they can not slow down, but work themselves to the point where something gives way, in most cases the cardiovascular renal complex. The fact that approximately sixty per cent. of white males now sixty years of age will die from cardiovascular renal diseases constitutes a warning.

This picture of aging is drab and depressing. Though death is inevitable and people are not given an even start by their fathers and mothers, it is not

all gloom. Some factors in aging, if not greatly overshadowed by disease, are assets. The poet, Emerson, has truly written, "At fifty years, 'tis said, afflicted citizens lose their sick-headaches . . . 'tis certain that graver headaches and heartaches are lulled once for all, as we come up with certain goals of time. The passions have answered their purpose: that slight but dread overweight, with which, in each instance, Nature secures the execution of her aim, drops off. To keep man on the planet, she impresses the terror of death. To perfect the commissariat, she implants in each a certain rapacity to get the supply, and a little oversupply, of what he wants. To secure the existence of the race, she reinforces the sexual instinct, at the risk of disorder, grief and pain. To secure strength, she imparts cruel hunger and thirst, which so easily overdo their office, and invite disease. But these temporary stays and shifts for the protection of the young animal are shed as fast as they can be replaced by the nobler resources." (Quoted from W. R. Miles).

This logical statement in terms of function does credit to Emerson as one far from ignorant of the principles of physiology. Trying to carry his idea a little farther we may ask what are some of these nobler resources, or assets, which the aged acquire?

As the years fly by there is a marked tendency, which should be cultivated, to recall pleasant happenings and to forget the painful ones. The individual becomes more mellow, easier to live with, especially for those not in the immediate family, and less exacting in his demands. In all healthy aging personal ambition gives way to a constructive interest in others, particularly the youngsters whose way they wish to make easier. This urge is indeed so strong that it is difficult to persuade the aged to inform us of their own problems, which we can only imagine imperfectly since we have not dealt with them personally. It would be a great contribution to human welfare if a few of those who have aged best would inform us how to profit by their example. Probably the mind of the aged will never be fully understood by youth. The metamorphosis has been too profound. Both young and old must help each other.

Another very frequent asset of the aged is increase in tolerance of the misdeeds of others. In their own lives they have found how easy it is to err. As a rule there is also an increase in breadth of view. From early absorption in their own career interest shifts to the expanding family to the whole nation and often to all mankind. But interest may narrow. That is to be guarded against. The greater experience of the aged gives them more maturity of judgment and provides the basis for the wisdom that all great civilizations have recognized as their potential prerogative.

As routine duties drop away they have more time at their disposal. The most universal attribute of the aged is that they yearn to be of use. Since the percentage of people of 65 years and over doubled from 1860 to 1930 (2.7–5.4%) and will probably slightly more than double again from 1930 to 1970 (5.4–11.8%), to make this increasing number of use is essential if we are to mobilize national resources. Yet there has been no consistent effort to tap this source of power. The chief obstacle is that the aged are more individualistic. This is because they have enjoyed a greater opportunity for diversification owing to a longer period of adjustment to changing conditions. They can not be so easily marshalled in groups, each group discharging a particular service.

Some old people are not so distracted by pain as younger ones afflicted in the same ways. Critchley has remarked "how often severe thoracic or abdominal disease exists in the aged without pain;

an extensive pneumonia or peritonitis can be entirely unsuspected; gall stones and renal calculi may be passed without the ordinary colic . . . minor surgical operations and dental extractions can be carried out with little pain and discomfort. The catastrophe of coronary thrombosis can take place with none of the agonizing symptoms found in younger individuals." Lastly, death itself, in the majority of cases, comes easily, usually unrealized by them.

As to the factors that retard aging and permit the realization of these and other potential assets, all who have given the matter a little thought will probably agree that the following are among those most commonly applicable. One of them, beyond our control, is to have been blessed with a good heredity, to have been constructed of materials that age slowly. Since aging bears a remarkably close resemblance to wear and tear it goes almost without saying that excesses of whatever nature are contraindicated; but, to maintain normal function, use is essential.

Purposeful adjustment of activities to the basic changes in structure, which have been but inadequately outlined, is necessary. It is the well adjusted people who age gracefully and usefully. Action on periodic advice by a skilled physician of the old guide, philosopher and friend type, if one can be found, is a potent factor in this connection. It is likely that he will in all cases rely partly on two measures. The first is to take full advantage from the conditioning influence of change. Monotony is deadly. Nobody wants to rust away. Change of almost any kind, whether of medication, of diet, of tempo and kind of activity, of environment, if not too radical, is helpful; because it promotes invigorating physiological and mental adjustments through the calling into action of certain functions and the resulting relief of strain on others. But the chief factor in realization of the assets is to cultivate far in advance some socially useful activity to which he or she is suited, however small, and to enjoy a feeling of continued accomplishment to the end, strengthened—it is important to note—by recognition of its value by friends and relatives.

Some conclusion such as this must have been in the mind of John Dewey when he remarked[1] "I am unable to see how the basic *human* problem can be solved without social changes which ensure to every individual the continual chance to have intrinsically worthwhile experience, and secondly provide significant socially useful outlets for the maturity and wisdom gained in this experience." Indeed this declaration is a kind of social *Magna Charta.*

[1] "Problems of Ageing," edited by E. V. Cowdry, Baltimore: Williams and Wilkins, 1942.

BOOKS ON SCIENCE FOR LAYMEN

MEDICAL PSYCHOLOGY THROUGH THE AGES[1]

NEARLY every one is interested in why people behave as they do. The mere fact that the newsstands are covered with pulp magazines on "applied psychology" or "personality" indicates that this interest is not at all limited to the serious student of human behavior. Psychiatry has of late years become an important medical specialty, and its influence has been felt in many fields—anthropology, law, and social sciences in general.

Doctors Zilboorg and Henry have here presented a comprehensive study of the evolution of the medical concepts of mental functioning, and in so doing have placed the student of behavior immeasurably in their debt. A perusal of this scholarly volume indicates some of the reasons why mental medicine has always remained on a somewhat different footing from the rest of medicine, and through what vicissitudes the mentally ill have passed in their struggle to be understood and treated intelligently. "In no other field of disease," says Zilboorg, "is there so much avoidance of medicine in the form of widespread quackery, that is, non-medical philosophizing on 'reeducation,' 'psychological or psychoanalytic guidance,' by various non-medical amateurs, lay or clerical."

The Greeks made the first attempt to consider mental diseases scientifically. Hippocrates was rash enough to deny that epilepsy was a "sacred disease," and he described phobias, delirium and paranoia. The Dark Ages of Medicine, however, the principal author points out, began with the death of Galen in 200 A.D. Superstition, magic and a belief in demons who affected mind and body developed, and medical psychology was taken over by the priests, a state of affairs that lasted for twelve centuries. The annals of the treatment of witches make our blood run cold even to-day, but for centuries there was no one to raise his voice to protest in the name of medicine and humanity. By the fifteenth and sixteenth centuries, however, men like Weyer, Vives, Plater and Paracelsus exhibited independent thought and once again began a spirit of scientific inquiry.

The tide of inquiry swept on in other fields as well—Galileo, Newton and Wren in their lives and Sydenham, the father of English medicine, in his. Mental medicine, however, still lagged, and it was not until the end of the eighteenth century that any real hospitals for the mentally ill were established, under the influence of Tuke and Pinel.

The early nineteenth century witnessed a flood of investigations and investigators—Mesmer, Braid and Bernheim, with their work on hypnotism; Charlot, Janet, Kraepelin, and a host of others, and in our own time Freud, Meyer, White and Brill.

"This century presents only the beginning. . . . The 2,500 years of psychiatric history which are behind us have been but preliminary centuries which cleared the field of operations and prepared the ground for a true psychiatry."

Dr. Henry contributes two chapters, one on "Organic Mental Diseases" and one on "Mental Hospitals."

The volume is not only a valuable historical document; the material is presented in a literary style which is unfortunately all too rare in medical works. It is a work which will be found interesting and stimulating and enjoyable by the readers of THE SCIENTIFIC MONTHLY.

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SAINT ELIZABETHS HOSPITAL,
WASHINGTON, D. C.

[1] *A History of Medical Psychology.* Gregory Zilboorg. Illustrated. 606 pp. $5.00. 1941. W. W. Norton and Company.

INDIANS OF SOUTH AMERICA[1]

THE aim of the author of "Indians of South America" was to give a general survey of the main aboriginal cultures of that area. This has been done in a most readable way, and at the same time many false notions have been exposed and much new material is presented.

Much time has been spent discussing cannibalism among the aborigines of South America and many scholars have argued that it did not exist, but Mr. Radin feels it best to give the facts. He points out that cannibalism did exist, that it has been practiced in many parts of the world, and that there is an intimate connection between cannibalism and warfare and also with human sacrifice. Many peoples who did not practice it were accused of it by white men who thus rationalized their maltreating or even their killing of the Indians. But "the Spaniards, Portuguese, French, English and Dutch demonstrated within a few generations of the discovery of America that the Carib were bungling amateurs at the game of torment and destruction and death" (p. 72).

A discussion of the origin of the American Indian has long been a favorite sport. It is well known that peoples migrate great distances, but it is hard to tell how much culture they brought along, how much they developed *in situ*. Many authors have postulated such huge folk wanderings among American Indians that it would seem necessary to suppose that there was in existence a pre-Conquest steamship company bringing Mayans to Peru and Ecuador, for instance. Mr. Radin does not fall into such pitfalls. That the ancestors of American Indians filtered into America from Asia gradually with little of the paraphernalia of civilization would seem to be self-evident. Hence they developed their civilizations and cultures in those places most propitious for human occupancy—namely, the high mountains, above the mosquito line or the tropical deserts where irrigation was possible and sunshine active in killing bacteria.

Lay readers will probably most enjoy Part III—"The Great Civilizations." Many were the tribes in which economic collectivism flourished, but it was left to the Incas to bring this type of economy to full flowering. Under them the land was wholly worked by the people; every one had to work, but no one was overworked. The amount of goods and services received by the church, the individual, the Inca and the army were rigidly fixed, and there was a rigorous caste system consisting of nobles and commoners, between whom marriage was prohibited. Upon this smoothly working society the Spaniards superimposed the yoke of feudalism, which the Indians have spent 400 years in throwing off—or trying to throw off. The author concludes his analysis with the following keen observations: "The Indian and the *mestizo* have always remained an important element of the population, whose demands for recognition were repeatedly voiced; sometimes peacefully, more frequently, violently. To-day these demands have become more insistent and more coherent, as one might expect from a group constituting at least 20 per cent. of the native population of the continent, roundly 18,000,000 people. No stable peace and prosperity can ever come to the republics of this great region unless these demands are granted and the Indian and the *mestizo* are permitted to participate, on equal terms, with the whites. In no part of the world have the culturally dominant whites so excellent an opportunity of redeeming themselves or, better, of being forced to redeem themselves as in South America. Let us hope they will take advantage of it."

RAYMOND E. CRIST

[1] *Indians of South America.* Paul Radin. Illustrated. xvii + 324 pp. $4.00. 1942. Doubleday, Doran and Company.

AN UNUSUAL BOOK ON INSECTS[1]

"NEAR HORIZONS" is described in the foreword as "The Travel Book of a man who stayed at home." It is the record of observations in a wild garden that was maintained by the author for the use of insects and not for their destruction. It is filled with beautiful photographs (more than 160 of them, mostly close-ups) that illuminate the stories of the insects under observation. These are pictures not of "specimens," stuck on pins and symmetrically "spread," but mostly of living insects as they would be seen by the reader of the book, in natural attitudes and against their natural backgrounds of bark and spray and flower, of earth and nest and burrow. They are mostly enlargements that bring out strikingly the characteristics of the animals studied, and that will enable the reader who is untrained in entomology to recognize them on his own walks afield.

The accompanying text contains a large amount of up-to-date information, interestingly told. Since insects are not the only denizens of the garden, other animals receive considerable attention, especially in the chapters entitled "Birds in an Insects Garden" and "Mole's Way." One most interesting and valuable chapter is worthily devoted to "The Cicada Man," the well-beloved, octogenarian entomologist, William T. Davis, of Staten Island.

An "Entomological Epilogue" at the end of the book lists nearly a hundred different insects that are discussed in the text, and serves as a repository for the big scientific names that might frighten the general reader, while keeping them available to those who may require them.

It is an excellent book. Like the garden of which it treats, there is something in it for every one.

JAMES G. NEEDHAM

[1] *Near Horizons. The Story of an Insect Garden.* Edwin Way Teale. Illustrated. xiv + 319 pp. $3.75. October, 1942. Dodd, Mead and Company.

FROGS AND TOADS OF NORTH AMERICA[1]

THE authors, drawing from the works of a half hundred other authorities, and combining with their own intensive observations made over many years, present a handbook that is completely what the name implies.

The part on breeding habits, the eggs, tadpoles and their transformation, is followed by a series of unusually excellent keys to families, genera and species, accompanied by most helpful sketches, so well done and so well labeled that even a beginner should have little difficulty in identifying the specimens.

Each of the ninety-two forms occurring in North America is figured by a series of original photographs of living specimens, showing dorsal, ventral and lateral views, and some with eggs and tadpoles. The range of each species and the general characteristics of each are given, with notes on the voice and breeding habits, and many personal notes made in the field by the authors. There is an amazing list of common names and a complete bibliography, including state and province lists.

To teachers, students and naturalists, for whom the work is designed, it is a most important contribution to our list of works on Amphibia.

W. M. MANN

[1] *Handbook of Frogs and Toads.* Anna Allen Wright and Albert Hazen Wright. Illustrated. xi + 286 pp. $3.00. 1942. Comstock Publishing Company.

NIKOLA TESLA

A PHOTOGRAPH TAKEN ABOUT 1885, SHORTLY AFTER HE CAME TO THE UNITED STATES.

THE PROGRESS OF SCIENCE

NIKOLA TESLA, 1857–1943

WITH the death of Nikola Tesla in New York City on January 7th, 1943, there passed a man whose inventions in the field of alternating current power transmission exerted a profound effect upon the development of the electrical industry, whose investigations in the field of high frequency currents brought him to the threshold of the discovery of wireless signalling, and phose prophecy of the advent of radio broadcasting nearly forty years ago, with all its social implications, has been fulfilled with an accuracy which is almost uncanny.

He was born of the Serbian race in 1857 at Smiljan Lika on the then borderland of Austria-Hungary. After attending the local schools, he finished his studies at the Polytechnic School of Graz, Austria, and at the University of Prague. Specializing in physics and mathematics, it appears that at the Polytechnic School he became acquainted with the rotating electrical machinery of that day and was much impressed by the mechanical weaknesses and general undesirability of commutators and brushes, an observation which was later to lead to his most important invention. After spending a few years obtaining practical experience in the electrical art at the centers of activity on the continent, in 1884 he came to the United States and secured employment at one of the Edison companies which were then engaged in the development of the direct current lighting system.

In the succeeding years, the idea of eliminating brushes and commutators by means of a rotating magnetic field began to take form in his mind and resulted in the invention of the induction motor and the polyphase transmission system. In 1887 the Tesla Electric Company was formed to develop these ideas and shortly thereafter the Westinghouse organization, appreciating the possibilities of the system, took it up as a major project. The tremendous potentialities of the alternating current system were explored and extended, and as its advantages became more clearly apparent, other organizations bent their efforts in the same direction. On this part of Tesla's career much will probably be written by men whose actual contact with the work qualifies them better than the writer to speak.

The work of practical design and exploitation having passed into hands more able to carry it on, Tesla began a series of painstaking investigations of the effects of high frequency, high voltage currents, which were to bring him to the brink of the discovery of radio signalling. It is not clear from his lectures what the motivating force was which initiated these investigations. He appears to have started by utilizing the ordinary spark induction coil, but energized it by specially designed alternators giving frequencies of the order of 10,000 cycles. Apparently he observed and understood the effects of resonance and distributed capacity in the equipment, for we find him, in order to produce currents of still higher frequencies, proceeding to the invention of the oscillation transformer with its primary excited by currents from the discharges of a condenser across a spark gap—the now well known "Tesla Coil." With this mechanism he produced brush discharges at extraordinarily high voltages, and demonstrated many new and striking effects.

His lectures, delivered in the years 1892 and 1893 in the United States and Europe, disclosed a long series of experiments relating to the application of these

currents for the production of light in various ways from evacuated filamentless tubes.

There is in the lecture delivered before The Franklin Institute in 1893 a proposal of a method of signalling "without the use of wires," which, had it been followed up experimentally, might well have led to the discoveries which were later to be made by Marconi. It seems to have been some kind of intuition that led Tesla to propose nearly all the means by which radio signalling was originally practiced. He proposes to disturb "the charges of the earth" by setting up alternating or oscillating currents in an elevated conductor connected to an alternating current machine or to one of his oscillators whose other terminal is connected to the earth. As a receiving means he proposes to set up an elevated conductor resonated to earth to respond to the transmitter. All that he failed to describe, from an apparatus standpoint, was some suitably sensitive device to indicate or to detect the received signals.

There is a very reasonable possibility that had Tesla proceeded experimentally along these lines, he would have met with success. It would not have been the first time that an important discovery was made by following an erroneous theory.

For many years Tesla conducted experiments in a laboratory erected in Colorado, and later at a plant located at Wardenclyffe, Long Island, to follow out his theory, now extended to include also the transmission of power by "wobbling the charges of the earth." No technical account of these experiments has ever appeared.

Yet in his last publication on the subject there appears what might almost be termed a vision of the destiny of radio, so clearly did he forecast its all important field of utility and service—broadcasting. A part of it is quoted herewith from the Appendix of his book, published in 1904, entitled "Experiments with Alternate Currents of High Potential and High Frequency." Referring to his plans for the utilization of his own system he states:

> I have no doubt that it will prove very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions, and that it will add materially to general safety, comfort and convenience, and maintenance of peaceful relations. It involves the employment of a number of plants, all of which are capable of transmitting individualized signals to the uttermost confines of the earth. Each of them will be preferably located near some important center of civilization and the news it receives through any channel will be flashed to all points of the globe. A cheap and simple device, which might be carried in one's pocket, may then be set up somewhere on sea or land, and it will record the world's news or such special messages as may be intended for it."

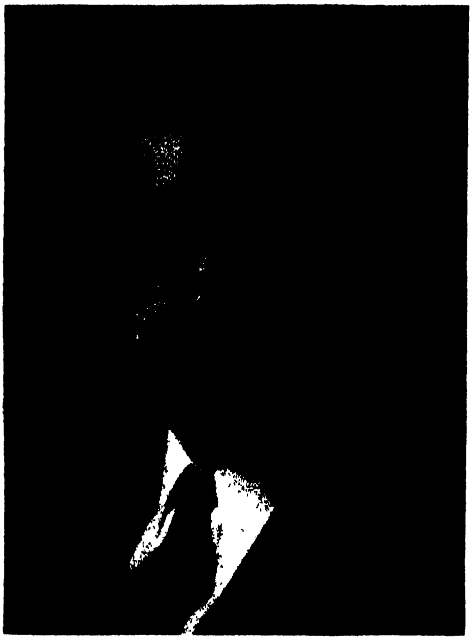
Of course the instrumentalities for practicing broadcasting were not then in existence. Tesla was classed as a visionary and his prophecy was forgotten. What harsher terms might, with justice, be applied to many of us who helped produce the instrumentalities with which broadcasting was eventually accomplished! We applied them to point-to-point communication, failing completely to realize the significance of Tesla's words.

EDWIN H. ARMSTRONG

NEWLY ELECTED VICE-PRESIDENTS OF THE AMERICAN ASSOCIATION

THE American Association for the Advancement of Science organizes its programs under fifteen sections which together cover broadly the fields of the natural and the social sciences. The affiliated societies which meet with the Association present their programs either jointly with the sections in their respective fields or independently, as may best serve the interests of science.

Each of the fifteen sections of the Association has a chairman, elected for one



DR. FRANCIS D. MURNAGHAN
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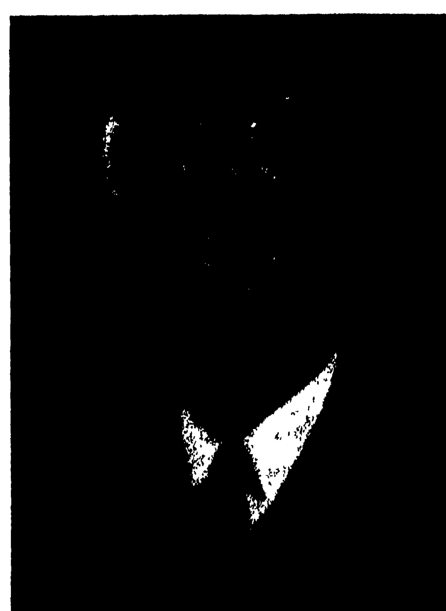
DR. OTTO STRUVE
PROFESSOR OF ASTRONOMY AND ASTROPHYSICS AND DIRECTOR OF THE YERKES OBSERVATORY; CHAIRMAN OF THE SECTION ON ASTRONOMY.

DR. J. W. BEAMS
PROFESSOR OF PHYSICS, UNIVERSITY OF VIRGINIA, CHAIRMAN OF THE SECTION ON PHYSICS.

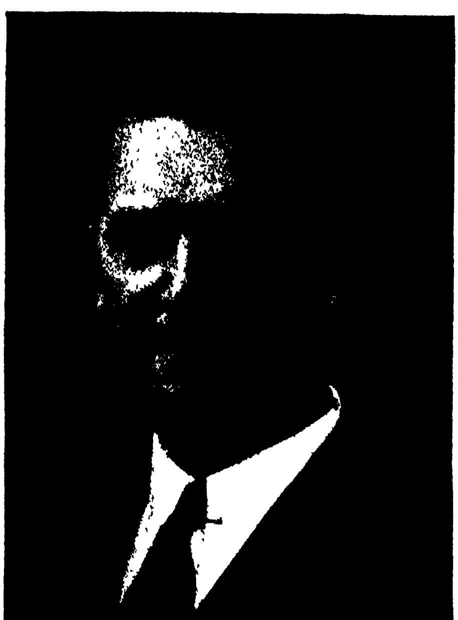


DR. ARTHUR J. HILL
PROFESSOR OF ORGANIC CHEMISTRY, YALE UNIVERSITY; CHAIRMAN OF THE SECTION ON CHEMISTRY.

DR. HERBERT WOODROW
PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF ILLINOIS; CHAIRMAN, SECTION ON PSYCHOLOGY.

year, who is a vice-president of the Association for the section. The vice-presidents are chosen from among the most eminent American scientists in their respective fields. Each vice-president delivers an address at the close of his term of office before the section of which he is chairman. As a rule, these retiring addresses are surveys of parts or all of the fields of the respective sections and often are distinguished contributions to science.

Among the eminent men who, before 1910, were vice-presidents of the Association for the section on mathematics and astronomy, which were joined in one section until 1920, we find J. Willard Gibbs, R. S. Woodward, later President of the Carnegie Institution of Washington, and E. E. Barnard, one of the greatest astronomers of his generation. The vice presidents of the section on physics included H. A. Rowland, A. A. Michelson, a Nobel Prize winner, Cleveland Abbe,



DR. CARL R. MOORE
PROFESSOR OF ZOOLOGY, THE UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON ZOOLOGICAL SCIENCES.

DR. WILLIAM J. ROBBINS
PROFESSOR OF BOTANY, COLUMBIA UNIVERSITY AND DIRECTOR, NEW YORK BOTANICAL GARDEN; CHAIRMAN OF THE SECTION ON BOTANICAL SCIENCES.

Elihu Thomson and Henry Crew. Among the vice-presidents of the section on chemistry there were E. W. Morly, who cooperated with Michelson in the ether-drift experiment, W. A. Noyes and Edgar F. Smith. The geologists and geographers held meetings under the chairmanship of T. C. Chamberlin, G. K. Gilbert, W. M. Davis and Bailey Willis. The section on zoology had among its presiding officers Henry F. Osborn, L. O. Howard, David Starr Jordan, E. G. Conklin and C. J. Herrick. Among the vice-presidents in the field of botany there were Charles R. Barnes, William Trelease, C. E. Bessey and D. T. MacDougal. The vice-presidents for the section on anthropology and psychology included D. G. Brinton, Franz Boas, J. McKeen Cattell, Hugo Munsterberg and R. S. Woodworth, while the section on physiology and experimental medicine numbered among its presiding officers William H. Welch, Simon Flexner, Ludwig Hektoen and William H. Howell.

DR. R. E. BUCHANAN

PROFESSOR OF BACTERIOLOGY, IOWA STATE COLLEGE; CHAIRMAN, SECTION ON AGRICULTURE.

DR. F. STUART CHAPIN

PROFESSOR OF SOCIOLOGY, UNIVERSITY OF MINNESOTA; CHAIRMAN OF THE SECTION ON SOCIAL AND ECONOMIC SCIENCES.

DR. HENRY E. SIGERIST

PROFESSOR OF HISTORICAL MEDICINE; THE JOHNS HOPKINS UNIVERSITY; CHAIRMAN, SECTION ON HISTORICAL AND PHILOLOGICAL SCIENCES.

DEAN THORNDIKE SAVILLE
PROFESSOR OF HYDRAULICS AND SANITARY ENGINEERING, NEW YORK UNIVERSITY; CHAIRMAN OF THE SECTION ON ENGINEERING.

DR. PAUL D. LAMSON
PROFESSOR OF PHARMACOLOGY, VANDERBILT UNIVERSITY SCHOOL OF MEDICINE; CHAIRMAN OF THE SECTION ON MEDICAL SCIENCES.

Although the men whose names have been mentioned were vice-presidents of the Association from thirty to sixty years ago, their influence on American science continues to this day.

Since 1920, when a revised constitution was adopted, the Association has had fifteen sections. Consequently during the twenty-two years since that time there have been more than 300 vice-presidents of the Association. The retiring addresses, most of which have been published in *Science*, present a picture of the progress of science in general during the period that probably can not be equaled in any other publication. Although it is uncertain whether the Association can hold a meeting next December, it is expected that the vice-presidents recently elected will prepare addresses and that they will be published.

All important officers of the Association are elected by the Council at its annual meetings held during the Christmas holiday season. However, the meeting scheduled to be held in New York City was canceled because of congestion in transportation and officers could not be elected in the normal way. Instead, the election was held by mail ballot of the Council, the votes being counted by the tellers on February 17. This innovation in the method of electing officers of the Association was at first regarded with some misgivings; but, like many other changes in ways of doing things and habits of thinking that have been forced by the war, it was found to have important advantages, the foremost of which is that a much larger fraction of the Council voted by mail ballot than has ever been able to vote at a meeting of the Association. A second advantage is that when a mail ballot is taken the members of the Council have time to act with deliberation. Possibly this experience will lead to a change in the method of electing officers of the Association.

The newly elected vice-presidents of the Association, whose portraits accom-

DR. JOHN K. WRIGHT
RESEARCH EDITOR, AMERICAN GEOGRAPHICAL SOCIETY, NEW YORK; CHAIRMAN OF THE SECTION ON GEOLOGY AND GEOGRAPHY.

DR. HAROLD F. CLARK
PROFESSOR OF EDUCATION, TEACHERS COLLEGE, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON EDUCATION.

pany this note,[1] are an interesting cross-section of American scientists. In the first place, they represent fifteen different fields. Eleven of the fifteen vice-presidents were born in the United States, one each in Connecticut, Iowa, Kansas, Kentucky, Missouri, Nebraska, New York and Ohio, and three were born in Massachusetts. Of the foreign born, Dr. F. D. Murnaghan was born in County Tyrone, Ireland; Dr. Otto Struve was born in Kharkov, Russia; Dr. Robert H. Lowie was born in Vienna, Austria; and Dr. Henry E. Sigerist was born in Paris, France. They hold positions in fourteen different educational and scientific institutions distributed throughout the United States from Connecticut to California and from Minnesota to Tennessee.

[1] With the exception of that of Professor Robert Lowie, Chairman of the Section on Anthropology.

Of the fifteen vice-presidents, twelve hold university positions in the usual sense, one is the director of a botanical garden, one is the director of two astronomical observatories, and one is a librarian and editor.

Since they range in age from forty-four to sixty years, with an average of fifty-three, they are near the zenith of their intellectual powers. Their memories reach back far enough to give them perspective, their vitality extends their vision into the future, and their achievements and present positions will enable them to exert a strong influence on American science at the very time when its greatest opportunities for making contribuitions to the progress of civilization are presented.

F. R. MOULTON,
Permanent Secretary

THE MENDEL MUSEUM AT MARY WASHINGTON COLLEGE

In the library building of Mary Washington College at Fredericksburg, Virginia, the memory of Gregor Mendel, a great man whose work was not appreciated until after his death, is perpetuated in a museum founded by the writer, professor of biology in the College and a refugee from Bruenn, where Mendel's epoch-making experiments on heredity were carried out.

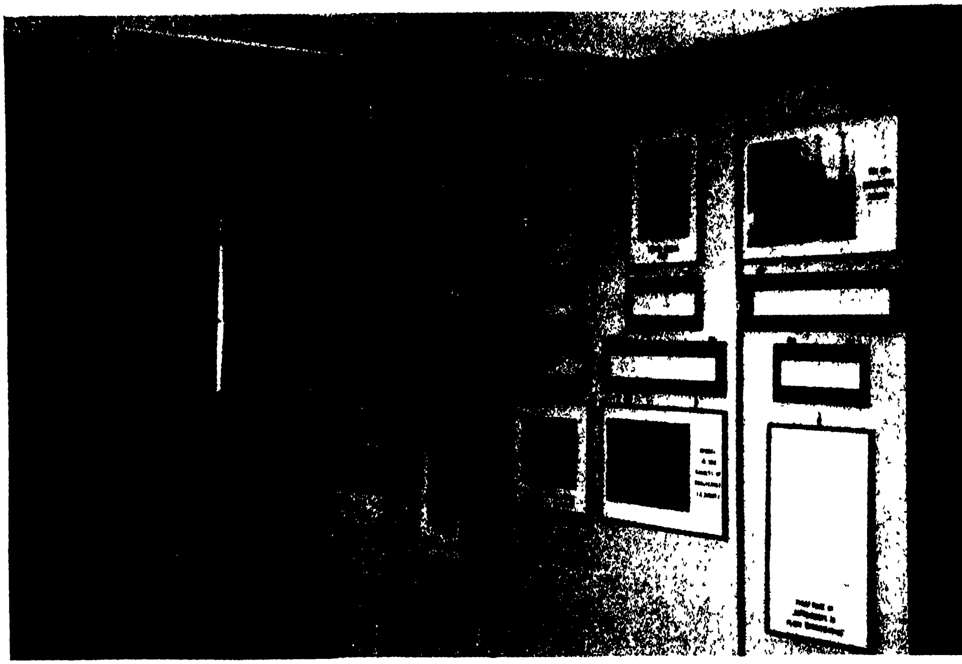
At present the museum occupies one large room in the library building at Mary Washington College. Four exhibition walls and one exhibition desk are now ready for inspection by the public. Each is divided into six compartments. In order to facilitate the study for the visitor, type-written explanations are placed beneath or above each object. The German text of the documents is translated into English. The first nine compartments contain the bibliographical material concerning Gregor Mendel's life and work, arranged around the portrait of Gregor Mendel, painted by Joseph O. Flatter. This portrait painter, now a citizen of England, had been working in Bruenn for many years, during which he studied the environment where Mendel's work originated, all the existing portraits and photographs of Mendel and the characteristics of the living relatives of the great scientist. In this way he succeeded in catching the expression of Mendel's true personality. The landscape of the background is that of the country around Bruenn.

The exhibition starts with the photograph of the modest farm house where Mendel was born, shows photostats of his autobiography, of the first page of his classical paper, all existing portraits and photographs of Mendel, the monastery where he lived, his experimental garden, etc. The tenth compartment shows the portraits of some of the outstanding forerunners of Mendel in plant-hybridization from R. J. Camerarius, the German who discovered the sexuality of plants until W. J. Spillman, the American, who in 1899 discovered the Mendelian principles of wheat, independently and without knowledge of Mendel's work. The compartments eleven to eighteen contain the preparations of the original experiments of the pea as made by Mendel, the proof of his theory by the back-cross experiment and the modern explanation of the experiments by the modified Punnett checkerboard. The compartments nineteen to twenty-four contain material connected with the rediscovery of Mendel's results, the Mendel celebration and the Mendel Memorial in Bruenn and with the foundation of modern genetics.

On the exhibition desk the valuable original documents, partly written by Mendel's hand, are shown. Some of them are connected with the examination for the office of a teacher at the Gymnasium. Unfortunately, Mendel did not go to the University before this examination, but afterwards. Thus he was not prepared sufficiently and it happened that the great discoverer in the field of Natural Science failed at his examination on natural science.

On the lower part of one of these documents is written in Mendel's beautiful and clear script, in German, "The respectful undersigned acknowledges that he received the questions for homework about natural science for the whole Gymnasium from the Imperial Royal Examination Commission." Six weeks later Mendel sent his elaborated answer to Vienna. The certificate about this examination by Professor Kner is almost annihilating.

Another interesting Mendel relic consists of a collection of leaves of pears with Mendel's handwriting. From the time of his youth, Gregor Mendel retained his fondness for fruit growing. After his election as prelate, he became master of the garden and had sufficient money to order and to cultivate the best



ONE OF THE EXHIBITION WALLS OF THE MENDEL MUSEUM

races of fruit trees. Pater Clemens Janetschek, parson of Altbruenn, one of the conventuals to whom Mendel remained in friendly relations until his last years, presented the biographer with this collection of the leaves of pear trees. On each leaf Mendel wrote the name of the variety in his characteristic handwriting.

Finally there are on the desks the original prints of the three papers published by Mendel in the "Proceedings of the Society of Natural Science in Bruenn." We see the original print of Mendel's "Experiments on Plant Hybridization," published in Bruenn in 1866, the second paper "On Some Hawkweed Hybrids Obtained by Artificial Fertilization" published in the same proceedings in 1870, and finally a paper describing and explaining scientifically the tornado, which devastated parts of Bruenn on October, 1870, proving Mendel to be also a distinguished meteorologist.

This is the part of the museum already finished. The large back walls and the two side walls will make it possible to enlarge the museum by demonstration of modern Mendelian experiments, of the results obtained by Drosophila research, of the modern study of the chromosome mechanism and of the practical application of Mendelism to plants, animals and man.

HUGO ILTIS

AWARD OF SCIENCE SCHOLARSHIPS TO HIGH SCHOOL STUDENTS

FORTY science scholarships, including two of $2,400, one for a boy and one for a girl, were awarded to twenty-nine boys and eleven girls in the second nationwide Science Talent Search concluded in Washington, D. C., on March 2. The scholarships, totaling $11,000, were awarded to graduating seniors in public, private and parochial schools.

Gloria Indus Lauer, of Ames, Iowa,

DR. HUGH S. TAYLOR, PROFESSOR OF CHEMISTRY, PRINCETON UNIVERSITY
EXPLAINS TO A GROUP OF SCHOLARSHIP CONTESTANTS HOW A HAIR OR SILK FIBRE WOULD LOOK IF MOLECULES WERE THE SIZE OF THE MODELS HE HOLDS IN HIS HANDS.

and Ray Reinhart Schiff, of New Rochelle, New York, each received a four-year Westinghouse Science Grand Scholarship of $2,400. Six other boys and two other girls received four-year Westinghouse Science Scholarships of $400 each. One-year scholarships of $100 each were awarded to thirty seniors who also attended the Science Talent Search Institute in Washington. The awards were made by Dr. Harlow Shapley, Director of the Harvard College Observatory and Chairman of the Science Talent Search board of judges, at a banquet held at the Hotel Statler on March 2, which closed a four-month quest for students of the greatest potential science talent among the million high school seniors of America.

Each recipient of a scholarship may attend any college or university of his choice that meets the requirements of the scholarship awarding committee. The awards do not prevent those winning the awards from accepting other scholarships.

Five alternates were named to receive awards if for any reason, except war service, winners should be unable to use their scholarships. Scholarships awarded to winners who enter military or other government service will be held in trust by Science Service for use after the war.

The Science Talent Search judges in addition to Dr. Shapley, chairman, were Dr. Harold A. Edgerton, Director, Occupational Opportunities Service, The Ohio State University, and Dr. Steuart Henderson Britt, Director of the Office of Psychological Personnel of the National Research Council and Professor of Psychology at George Washington University.

Last November 25,000 school principals and teachers were asked to assist in finding the forty graduating seniors en-

rolled in the nation's secondary schools who were most likely to succeed as scientists. These principals and teachers responded by administering a science aptitude examination, prepared for the Search by Dr. Edgerton and Dr. Britt, to 15,000 entrants. On the basis of this examination, as well as an original essay of 1,000 words on "Science's Next Great Step Ahead" and personal and scholarship records submitted by the teachers, forty of the entrants were chosen to go to Washington for a five-day Science Talent Search Institute. Final examination during sessions of the Institute, and individual interviews with the judges, determined the award of the scholarships.

The Science Talent Search is conducted annually by the Science Clubs of America, administered by Science Service, and the Westinghouse Electric and Manufacturing Company. The Westinghouse Company provides the scholarships as an incentive to scientific achievement in America.

The objectives of the Science Talent Search are:

1. To discover and foster the education of boys and girls whose scientific skill, talent and ability indicate potential creative originality and warrant scholarships for their development.

2. To focus the attention of large numbers of scientifically gifted youths on the need for perfecting scientific and research skill and knowledge so that they can increase their capacity for contributing to the task of winning the war and the peace to follow.

3. To help make the American public aware of the role of science in the war and in the post-war reconstruction.

EMBREE G. JAILLITE

A SCIENCE MOBILIZATION BILL

SUMMARY PREPARED BY THE SUB-COMMITTEE ON TECHNOLOGICAL MOBILIZATION

A PIONEER attempt to accord science full opportunity to contribute to the war effort crossed the nation's political horizon in August, 1942, when Senator Harley M. Kilgore of West Virginia introduced a Science Mobilization Bill in the 77th Congress. The measure was revised in accordance with constructive suggestions by numerous scientists and technologists and re-introduced in both houses of the 78th Congress by Senator Kilgore, in the Senate, and Congressman Wright Patman, in the House of Representatives.

Extensive hearings on the earlier bill were conducted last fall by the Senate's Kilgore Committee. Hearings on the current legislation are scheduled to begin in the week of March 22.

The Kilgore-Patman Bill (S. 702, H.R. 2100) provides for complete mobilization, development and application of scientific and technological resources, manpower and facilities for production of the war and for effecting transition from a national war economy to one of peace, during the forthcoming reconstruction period, with minimum dislocation and confusion insofar as technology is concerned.

Authors of the bill have recognized that America is engaged in a highly mechanized war, a technological struggle. The bill points to "serious impediments" to the full use of science and technology in the war, stating that the solution of urgent problems has been delayed or rendered ineffective by the absence of an over-all plan for the development and use of personnel and facilities in relation to the national need. It alleges further that there exists an insistent trend toward monopolized control of scientific and technical resources and a consequent lack of access thereto in the public interest.

Purposes of the bill are clearly stated in the document. Of particular interest to scientists are its intentions to aid and encourage the writing and publication of scientific literature; to promote full and speedy introduction of the most advanced and effective techniques for the benefit of agriculture, manufacturing, distribution, transportation and communication; and to aid and encourage research and enterprise of inventors, scientists, educational institutions, and public and private research laboratories.

It further declares as its purposes: the discovery and development of substitutes for critical materials; the promotion of interest in scientific education and provision for all qualified persons the means of scientific and technical training and employment; and the maintenance and expansion of free enterprise by making available to smaller business the benefits of scientific advancement.

To accomplish these and its other purposes, the bill proposes the establishment of an inedependent Office of Scientific and Technical Mobilization. This agency would have broad powers and would coordinate the work of twenty-odd major and more than forty minor government agencies now dealing with science and technology. In addition, it would initiate and maintain programs in those essential fields where no effective work is now being done.

The Office would be headed by an administrator appointed by the President. Dollar-a-year employees of the Office are expressly prohibited by the bill. The sum of $200,000,000 is authorized to be appropriated for carrying out the provisions and purposes of the bill.

Within the Office there would be a National Scientific and Technical Board, headed by the administrator and consisting of representatives of industry, labor, agriculture, consumer groups and two persons who are primarily scientists. All members would be full-time employees of the Office and would assist the administrator in carrying out the provisions of the bill. Because of its cross-section membership, the board would be equipped to reach equitable, non-discriminatory decisions in policy matters confronting the Office.

The bill also calls for a National Scientific and Technical Committee of twenty-five or thirty members. Headed by the administrator, it would consist of the board's membership and additional representatives of government agencies, industry, labor, the consuming public and science and technology. The Committee would meet at least once a month and would serve in an advisory capacity.

Board powers are granted to the Office. It would be authorized to (a) take a census of scientific facilities and provide archives for scientific material; (b) develop programs for full use of scientific and technical facilities and personnel; (c) coordinate work of Federal scientific agencies; (d) foster international cooperation in science; (e) advise the President and Congress, on request, regarding science and technology; (f) review specifications and designs and recommend their simplification when advisable; (g) finance scientific work, public or private, by loan or grant; (h) bestow merit awards for outstanding scientific contribution in the national interest.

The Administrator is empowered further by the bill to provide for deferment of scientific and technical personnel, thus preventing recurrence of such critical shortages as that which exists in the case of physicists, 2,000 of whom have been inducted into the Army, without regard to the need for their services in war production.

The bill pays particular attention to patents and specifically empowers the Office to requistion them, while a state of war exists, for use in the defense of the nation. It grants further to the Office exclusive power in the government over

all inventions and patents to which the government has claim which must be licensed on a non-exclusive basis and in such a way as to safeguard against monopoly or injury to the national interest.

The Office is also enabled by the bill to requistion any essential facility needed for war production when other means of obtaining use of the facility have been exhausted, with the proviso that they be restored to their owners within six months after the war has ended.

The bill, then, sets up an independent science and technology agency under the aegis of which the nation's scientific effort will be expanded in the war and post-war periods for maximum contribution to the general welfare of the nation.

The structure envisioned in the bill is all-embracing. Its program, as authorized by the bill, would enable science to assume a place at the highest level of the government. Until the introduction of this legislation science had been recognized only in part. Scientific divisions within government agencies had been established, and some few purely scientific agencies had been set up. But there had been no attempt to bring these together into a cohesive organization dedicated to the whole of science. The Office of Scientific and Technical Mobilization would accomplish this, would act as an advocate of science in the planning of national affairs where the voice of science is so desperately needed.

The timeliness of this legislation cannot be questioned. Science has so matured in the last twenty years that it demands this recognition. The war by its technological character compels us to mobilize our scientific resources now.

Extracts from Science Mobilization Bill

Definitions

"Scientific and technical personnel" shall include all persons, excepting physicians and dentists, who have completed any course of study in any college or university in any branch of science or its practical application or who have had not less than an aggregate of six months' training or employment in any scientific or technical vocation.

"Agency or establishment" shall mean any agency, board, department, office, bureau, or other body of the Federal or any State or local government, or any person, firm, or partnership engaged in business for profit, or any corporation, profit or nonprofit, association, school, college, and university.

Establishment of Independent Office

There is hereby created, as an independent agency of the Federal Government, the Office of Scientific and Technical Mobilization (hereinafter referred to as "the Office") which shall be administered by an Administrator to be appointed by the President, by and with the advice and consent of the Senate, and to serve at the pleasure of the President. The Administrator shall receive a salary at the rate of $12,000 a year. The Administrator shall appoint, fix the compensation, and define the authority and duties of such officers, employees, attorneys, and agents as he shall deem necessary to carry out the purposes and provisions of this Act and to transact the business of the Office. Such appointments shall be made in accordance with the provisions of the civil-service laws and regulations and the Classification Act of 1923, as amended: *Provided*, That when the Administrator determines it to be necessary in order to effecutate the purposes and provisions of this Act he may waive these requirements.

To formulate and promote projects and programs for the development and use of scientific and technical facilities and personnel and, when necessary, to initiate and carry out such projects.

To foster and develop scientific and technical methods, to promote their application in the national welfare, either within the Office or by other auspices, public or private, and to promote and provide training and participation in science and in its application.

To finance by loan, grant, exchange, purchase, or otherwise the operations or functions, or any of them, authorized by this Act, and, for the same purposes, to make or acquire any contract, guaranty, indemnity, stipulation, lease, or other instrument, to acquire, improve, and alter real and personal property, and to enter into any other transaction necessary or appropriate for the performance of its duties or powers.

To make, amend, and rescind appropriate rules and regulations to carry out the purposes of this Act and all the powers and duties vested in the Office, which rules and regulations shall have the force and effect of law.

Mobilization of Personnel

During the existence of a state of war and for six months thereafter, the Administrator is authorized to prescribe and promulgate appropriate rules, regulations, procedures, and methods, subject to direction by the Chairman of the War Manpower Commission, for the training, classification, and employment of all scientific and technical personnel by any person, agency, or establishment, public or private.

COMMENTS OF SCIENTIFIC MEN

Dr. Gustav Egloff, Director of Research, Universal Oil Products Company: You will be interested to know that there are now two bills by Kilgore, S-607 and S 702, "To establish an Office of War Mobilization, and for other purposes" and "To mobilize the scientific and technical resources of the Nation, to establish an Office of Scientific and Technical Mobilization, and for other purposes," both of which I believe are bad. S-702 is a revised bill of the one presented last year as S-2721.

Mimeographed copies of both the Kilgore bills are attached which I believe you will read with more than usual interest. I am hopeful that the A.A.A.S. may draw the attention of its membership to these two bills which will, should they eventuate into law, profoundly influence everyone's life adversely, and—more important—will slow up the war effort.

Dr. Harry N. Holmes, President American Chemical Society: I am much interested in your bill to establish an Office of Technological Mobilization, for I am convinced that we are not making war use of enough of our scientific brains. That is certainly true in chemistry, my own field. A great many chemists complain to me, as their president, that they want to do something to aid the scientific war effort but that no problems have been assigned to them.

Personally I am acquainted with important problems, some of them requiring pilot plants for development, that need directed drive. Needs and men should be brought together.

We have suffered from the bottleneck of military brains having the exclusive power to pass on to the research groups the problems to be investigated. Military men are not profound scientists, yet they have power to make vital decisions on scientific problems of vital importance to the war effort. . . .

Dr. Frank B. Jewett, President, National Academy of Sciences: . . . All this however, has nothing whatever to do with the Nation's scientific and technical preeminence. We forged ahead in the sectors open to us and built up a great potential reservoir of knowledge and trained personnel available for use in whatever direction need required.

During the past two years that direction has been increasingly away from civil and toward war objectives. Any of us who are in daily touch with the accomplishments of the Army, Navy, National Defense Research Committee, and latterly with the War Production Board know how astounding has been the progress. We are no longer laggards in this field but in many sectors are recognized leaders.

The figures I gave the committee are an illustration of how complete has been the transition from a peace to a war objective.

In the main this has been accomplished by utilizing existing agencies and directing their activity to war problems—not by setting up new agencies. The outstanding success of N. D. R. C. is grounded in a realization that new research and development agencies are very inefficient for a long time and that best results are obtained by utilizing men and facilities in situ so far as possible. We have stoutly refrained from building up a great centralized research and development organization and have adhered rigorously to the "no-profit no-loss" development contract scheme.

In only three substantial sectors has it been necessary to create new physical facilities and assemble large numbers of scientists and engineers by taking them away from their normal environment. These three were the two antisubmarine laboratories at New London and San Diego and the Microwave Laboratory at Massachusetts Institute of Technology.

As to the first two, there were no existing facilities and as to the third, no facility adequate for the work to be done. In all three cases, however, we adhered to the contract system in creating and operating the facilities in order to preserve going values.

Had we proceeded on the basis of setting up a centralized Government agency with paid personnel, as is contemplated in S. 2721 [the earlier Bill], I am sure we would have made a mess of it. Whether or not I am right in this I am certain that we have gone too far on the road we have followed to contemplate safely now so radical a change of philosophy as S. 2721 (and S. 2871) involves. . . .

Dr. Charles L. Parsons, Secretary, American Chemical Society: . . . There are many desirable objectives in this bill, but in my opinion it confers totalitarian powers that should be entrusted to no human being and requires an omniscience for its intelligent execution which is not to be found on this earth.

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MAY, 1943

CHINA AND AMERICA AGAINST SOIL EROSION

I. THE FATE OF CONSERVATION IN NORTHERN SHANSI

By Drs. W. C. LOWDERMILK and D. R. WICKES[1]

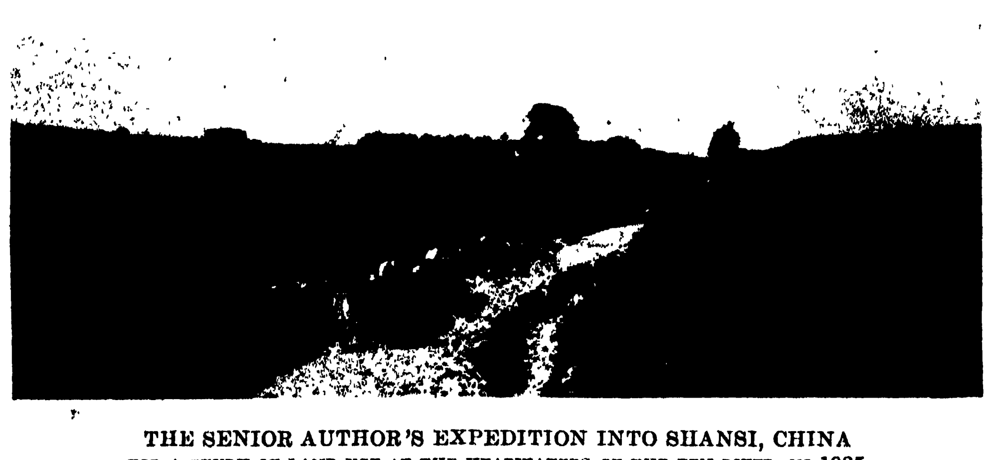
SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE

WAR of survival calls for our supreme effort. All resources, man-power and inanimate resources are called on to yield greater results. Experiments of the Soil Conservation Service throughout all farming areas of the country, have indicated that conservation measures greatly increase yields of crops. In such times our attention is called to China, where the use of land has gone through a wide range of trial and error for thousands of years. To find that conservation is not unknown in China's long history is of special interest to American scientists and historians of today. Forces in civilization for and against conservation of material resources become apparent in the remarkable Chinese historical records and in the land itself, which bears a record of past land use.

Conservation of forests and soils has long been a problem and concern of the Chinese despite usual impressions gained from denuded hills of China. The senior author set forth the basis for this conclusion in 1930.[2] As far back as 300 B.C. one of the precepts of Mencius read as follows: "If ax and hatchet are used in forests at suitable intervals of time, then

[1] Assistant Chief and Soil Conservationist, respectively.

[2] *Annals of Amer. Acad. of Polit. and Social Science*, 152: Nov. 1930.



THE SENIOR AUTHOR'S EXPEDITION INTO SHANSI, CHINA
FOR A STUDY OF LAND USE AT THE HEADWATERS OF THE FEN RIVER, IN 1925.

VIEW ACROSS THE VALLEY OF THE FEN RIVER

IN WHICH TUNG CHAI IS LOCATED, SHOWING A LANDSCAPE ONCE COVERED WITH SPRUCE-LARCH FORESTS. THE LAND IS CULTIVATED EVEN UP TO STEEP SLOPES AS SEEN IN THE RIGHT FOREGROUND, BRINGING ON DEVASTATING SOIL EROSION UNTIL MOST OF THE AREA HAS BEEN GENERALLY ABANDONED BY FARMERS, EXCEPT IN PATCHES, AS MAY BE NOTED IN THE MIDDLE FOREGROUND. NOW HERDS OF SHEEP RUN OVER THE ABANDONED FIELDS.

timber will be available when needed.'"[3] From ancient printed records of China, where the printing press was in use long before its discovery by Gutenberg,[4] there is evidence that conservation was not only understood and advocated but carried out for centuries. The Chinese have long been conservationists, second only perhaps to the ancient Phoenicians. The Chinese inherit an unbroken civilization for fully 4,000 years, while the Phoenicians long ago disappeared as a nation and as a people.

But knowledge and regulations for conservation were not enough to assure its lasting observance as a policy. Some of the reasons are set forth by the Senior author elsewhere.[2] Despite sound regulations certain forces brought on exploitation of lands and forests, which unleashed erosion and torrential floods that undermined the prosperity of extensive regions. It is not within the purposes of this paper to examine the causes for the failure and success of conservation policies and measures; its aim is rather to make known the record of a region in Shansi where policies for conservation waxed and waned through two cycles of several centuries.

The Chinese county or regional gazetteer is a remarkable historical source document. For more than 2,000 years it has been the custom in China to record

[3] Or in its context: If the seasons of agricultural work are not interfered with, grain will be more than can be eaten. If close-meshed nets are not used in pools or ponds, fish and turtles will be more than can be eaten. If ax and hatchet are used in forests at suitable times only, wood will be more than can be used. If grain, fish and turtles are more than can be eaten, and wood is more than can be used, this will cause the people to nourish the living and bury the dead without resentment. This condition, in which the living are nourished and the dead are buried without resentment is the beginning of the way of royal government. (Translation modified from Legge's in Chinese Classics, Vol. 2, p. 130 f. (1895.)

[4] See Carter, T. F. The Invention of Printing in China, 1925, ch. 10, etc.

[2] *Loc. cit.*

important events; many records of geographical facts and conditions and of important personalities have for nearly a thousand years been included in printed volumes issued from time to time by counties, prefectures and provinces. Each later issue summarizes material from earlier issues and brings the record up to date with recent and new information. In these remarkable gazetteers are accounts of eclipses, of severe droughts and destructive floods, of forests and land use, besides other information. Such documents, of which the Library of Congress has one of the world's most complete collections now numbering more than 3,000 gazetteers besides duplicates, afford much information concerning the history of land use and its consequences in typical areas of China.

More than ever are we of America interested in China, for now she is one of our most powerful and resourceful allies in this world-wide war. Moreover, our movement for conservation in the United States was stimulated by studies of land use in that ancient country. We should also remember that with a cultivated area of about two hundred million acres[5] China has for a long time been supporting a population of approximately 450 millions. Such effective use of land has not yet been approached in this country. Yet some have seen the danger that it will not continue in China without full use of conservation measures.[6]

President Theodore Roosevelt in a message to Congress in 1908 used China as an example of what happens when a country fails to preserve its forests, and pushed ahead the movement for conservation of forests in this country. Among other things he said:

> All serious students of the question are aware of the great damage that has been done in the Mediterranean countries of Europe, Asia, and Africa by deforestation. The similar damage that has been done in Eastern Asia is less well known. A recent investigation into conditions in North China by Mr. Frank N. Meyer, of the Bureau of Plant Industry of the U. S. Department of Agriculture, has incidentally furnished

[5] According to statistics published by the Ministry of Agriculture and Commerce, for 1917, a maximum figure. Ti chiu t'zu nung shang t'ung chi piao, 1920.

[6] Tieh, T. Min, Soil Erosion in China, *Geog. Rev.*, 31: pp. 570–590, 1941.

SAWING UP LOGS INTO BOARDS

FOR PACKING DOWN THE MOUNTAIN TO THE TOWN OF TUNG CHAI IN THE PROVINCE OF SHANSI.

in very striking fashion proof of the ruin that comes from reckless deforestation of mountains, and of the further fact that damage once done may prove practically irreparable. So important are these investigations that I herewith attach as an appendix to my message certain photographs showing present conditions in China. They show in vivid fashion the appalling desolation, taking the shape of barren mountains and gravel and sand-covered plains, which immediately follows and depends upon the deforestation of the mountains.

. . . Each family, each community, where there is no common care exercised in the interest of all of them to prevent deforestation, finds its profit in the immediate use of the fuel which would otherwise be used by some other family or some other community. In the total absence of regulation of the matter in the interest of the whole people, each small group is inevitably pushed into a policy of destruction which can not afford to take thought for the morrow. . . . The forests can only be protected by the State, by the Nation; and the liberty of action of individuals must be conditioned upon what the State or Nation determines to be necessary for the common safety.

The lesson of deforestation in China is a lesson which mankind should have learned many times already from what has occurred in other places. Denudation leaves naked soil; then gullying cuts down to the bare rock; and meanwhile the rock-waste buries the bottomlands. When the soil is gone, men must go; and the process does not take long.

This ruthless destruction of the forests in Northern China has brought about, or has aided in bringing about, desolation, . . . just as the destruction of the forests in Northern Africa helped towards the ruin of a region that was a fertile granary in Roman days. Shortsighted man, . . . when he has destroyed the forests, has rendered certain the ultimate destruction of the land itself. In Northern China the mountains are now such as are shown by the accompanying photographs,[7] absolutely barren peaks. Not only have the forests been destroyed, but because of their destruction the soil has been washed off the naked rock. The terrible consequence is that it is impossible now to undo the damage that has been done. . . . Almost all the rivers of Northern China have become uncontrollable, and very dangerous to dwellers along their banks, as a direct result of the destruction of the forests.

In the movement for conservation of natural resources which came after this message, though soil conservation was ably presented by Van Hise, Chamberlin and McGee, it was the idea of conserving

[7] Several of which are reproduced in this article.

CONTRAST VALLEY IN THE TUNG CHAI AREA

SO-CALLED BECAUSE A PORTION OF THE SLOPE WAS LEFT IN FOREST STAND AND THE REMAINDER CLEARED AND CULTIVATED. RUNOFF PLOTS WERE LOCATED IN THESE TWO AREAS TO SHOW CONTRAST IN RUNOFF AND EROSION UNDER THESE TWO CONDITIONS. LIGHTER COLORED AREAS ON THE CULTIVATED AREA SHOW EROSION PAVEMENT.

our forests that caught the public attention. Conservation of the soil, the basic resource, as a national policy essential to the general welfare had to wait for another generation and another Roosevelt as president.

Studies and experiments carried out by the Senior author on the ground in China[8] particularly in the provinces of Shansi, Shensi, Honan, Shantung, Anhwei, Chihli and Kiangsu, and research by the Junior author in Chinese historical records confirm the conclusions of the President's message, but with an important addition. Between deforestation and soil erosion with its far-reaching consequences of devastation is the process of cultivation to necessary crops. By this the soil formerly protected by its natural mantle of grass or forest is exposed to the dash of rain and blasts of wind to induce and speed up soil erosion. This erosion takes place at a rate faster than soil formation and means land destruction in any land if not controlled.

That large areas in North China now treeless were formerly covered with forest, woods and grass is recorded in documents that come down to us from the past. Among the gazetteers or local, prefectural and provincial histories in the Chinese collection of the Library of Congress there is ample evidence for extensive deforestation in the province of Shansi, as well as in other parts of China. The great Chinese Encyclopedia[9] confirms this evidence.

It has been asserted that the extensive areas covered with loess have never supported forests, on account of low water tables,[10] but the discoveries of J. G. Andersson in Honan Province seem to indi-

[8] Factors influencing the surface runoff of rain waters. Proc. Third Pan-Pacific Science Cong. Tokyo, pp. 2122–2148, 1926.

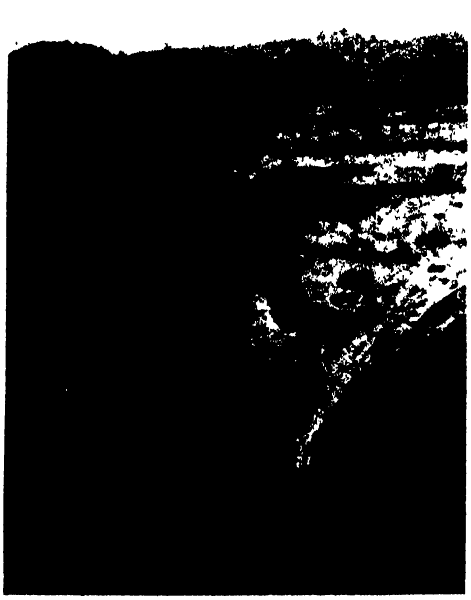
[9] Ku-chin t'u shu chi-ch'eng, compiled from important earlier works and carefully edited by a staff of scholars under imperial order. Preface 1726.

[10] V. K. Ting, Prof. Granet's "La Civilization Chinoise." Chinese *Social and Pol. Sci. Rev.*, 15: 267, 1931.

VIEW OF A MOUNTAIN SLOPE ONCE COVERED WITH FORESTS

AND THEN CLEARED FOR CULTIVATION, IN THE TUNG CHAI AREA. THE STUMPS AND ROOTS GRUBBED OUT OF THE GROUND WERE PILED IN WINDROWS ON THE CONTOUR, FORMING A SORT OF TEMPORARY TERRACE. EROSION HAS WASHED OFF THE SOIL, LEAVING HEAVY EROSION PAVEMENT AT THE SURFACE. ISOLATED TREES LEFT STANDING GIVE AN IDEA OF THE ORIGINAL FOREST COVER.

cate a considerable growth of trees in parts of this area in the period before the present deep gullying had lowered water tables.[11] As to the present, Sowerby, who has traveled extensively in this region states that "over the loess hills of Shensi, where uncultivated areas occur, we find such small trees as the Hazel, the Birch, a small variety of Poplar and a stunted Oak growing in great profusion, and forming dense coverts for various kinds of game."[12] Cressey in speaking



FOREST DENUDATION
SHOWING IN THE TUNG CHAI AREA HOW FORESTS WERE CUT AND THE LAND CLEARED FOR CULTIVATION, UNLEASHING TORRENTIAL RUNOFFS WHICH CUT GULLIES THROUGH THE LOWER SLOPES.

of the region of the loess highlands, says, "Much of the highlands, except perhaps the desert margins, appears to have once been covered with a continuous forest."[13]

A reasonable view is that zones of forest, brush and grass-land corresponded to rainfall belts as annual rainfall diminished toward the Gobi Desert, as studies of temple forests in extensive field surveys by the Senior author and Chinese associates have disclosed.[14, 15]

The process of forest removal and subsequent cultivation of the soil was observed by the Senior author in northern Shansi in Ning-wu Prefecture, near the sources of the Fen River. The effects of this combined process were also observed in eroded slopes and boulder-strewn dry stream beds, that became raging debris-laden torrents after heavy rains. Population pressure on land had pushed the cultivation line higher and higher up slopes where farming means more and more work. Following clearing of natural growth for cultivation, soil erosion develops gullies in the loess to astounding depths, often to the depth of the loessial mantle of several hundred feet, whereas erosion in residual soils washes away fine particles leaving behind rock fragments to form erosion pavement. Gullies may later cut through the erosion pavement to bed rock and fill the stream channel with gravel, cobble and boulders.

Ning-wu Prefecture, one of the study areas (now Ning-wu District) lies in the northwestern part of Shansi Province, about the headwaters of the Fen and Sang-kan Rivers. The topography is rough and mountainous with a little plateau land. The rainfall is in general convectional, occurring mostly as heavy downpours in summer. A mantle of loessial soil covers gently sloping land and lower flanks of the mountains. Wherever the loess occurs it has been cleared by eager farmers for cultivation. Above the loess mantle residual, noncalcareous

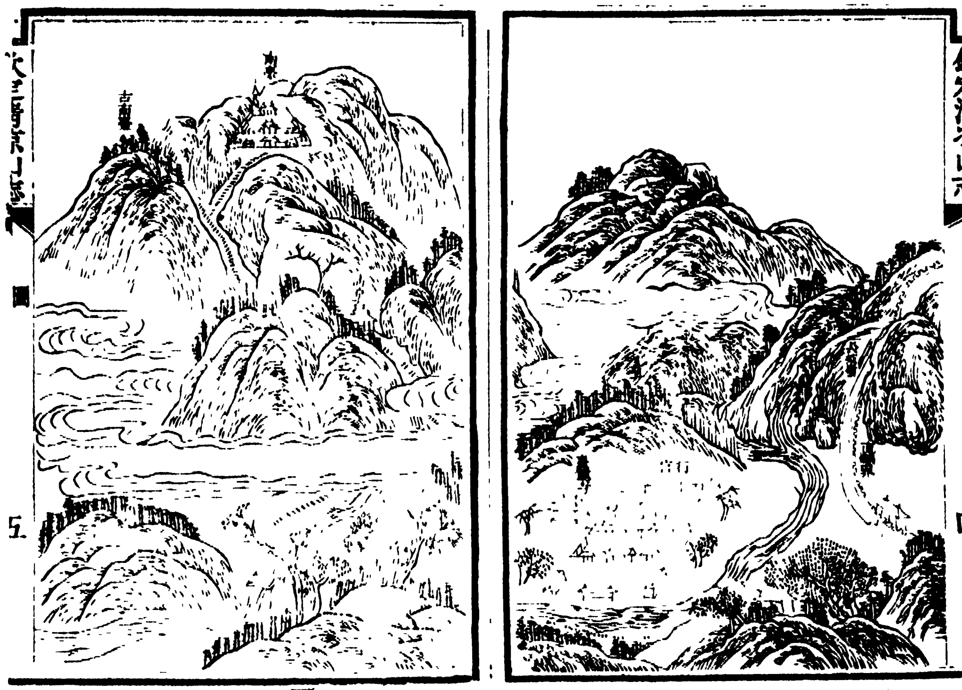
[11] Andersson, J. G., Children of the Yellow Earth, 1934, Chap. 10; Essays on the Cenozoic of Northern China. Memoirs of the Geol. Survey of China, Ser. A, No. 3, Mar. 1923, p. 141.

[12] Sowerby, A. de C. Sport and Science on the Sino-Mongolian Frontier, 1918, p. 221.

[13] Cressey, Geo. B., China's Geographic Foundations, 1934, p. 199.

[14] Lowdermilk, W. C., Forest destruction and slope denudation in the Province of Shansi, *China Jour. of Sci. and Arts*, 4: 127–135, 1926.

[15] Lowdermilk, W. C., T. I. Lee and C. T. Ren, A Cover and erosion survey of the Hwai River Catchment Area. In Chinese, Nanking, 1926: Ms. in English, S.C.S. Washington.



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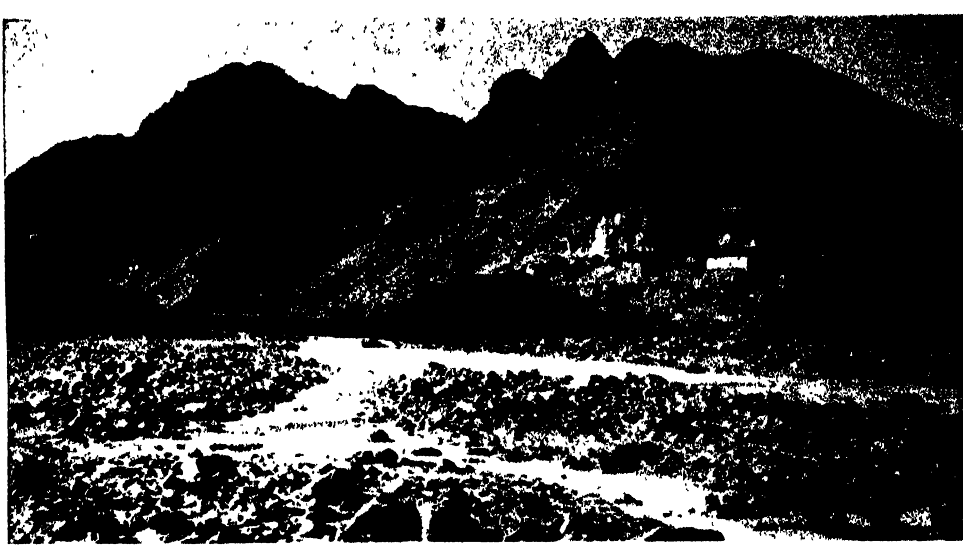
OLD CHINESE ILLUSTRATIONS FROM OFFICIAL GAZETTEER

PRESENTED TO THE EMPEROR IN A.D. 1786. THIS VIEW SHOWS THE SOUTHERN PLATFORM OF WU-T'AI SHAN AND ELEVATIONS TO THE SOUTHEAST, WITH FOREST REMNANTS.



Bailey Willis

BED OF THE T'AI-SHAN HO AT JUNCTION OF A TRIBUTARY

SHOWING DEPOSITED DETRITUS, BARED HILLS AND A VILLAGE WITH SOME CULTIVATION TERRACES IN LOESS DRIFT, MUCH OF WHICH HAS WASHED OFF THESE SLOPES.

gray brown podzolic soils mantle upper slopes and table lands of the mountains which were originally covered by excellent forest stands from pines at lower to spruce-larch at higher elevations.

The senior author found extensive forest remnants on mountains in the western part of the area, west of Tung Chai. On other slopes isolated forest trees

IN SHANSI PROVINCE

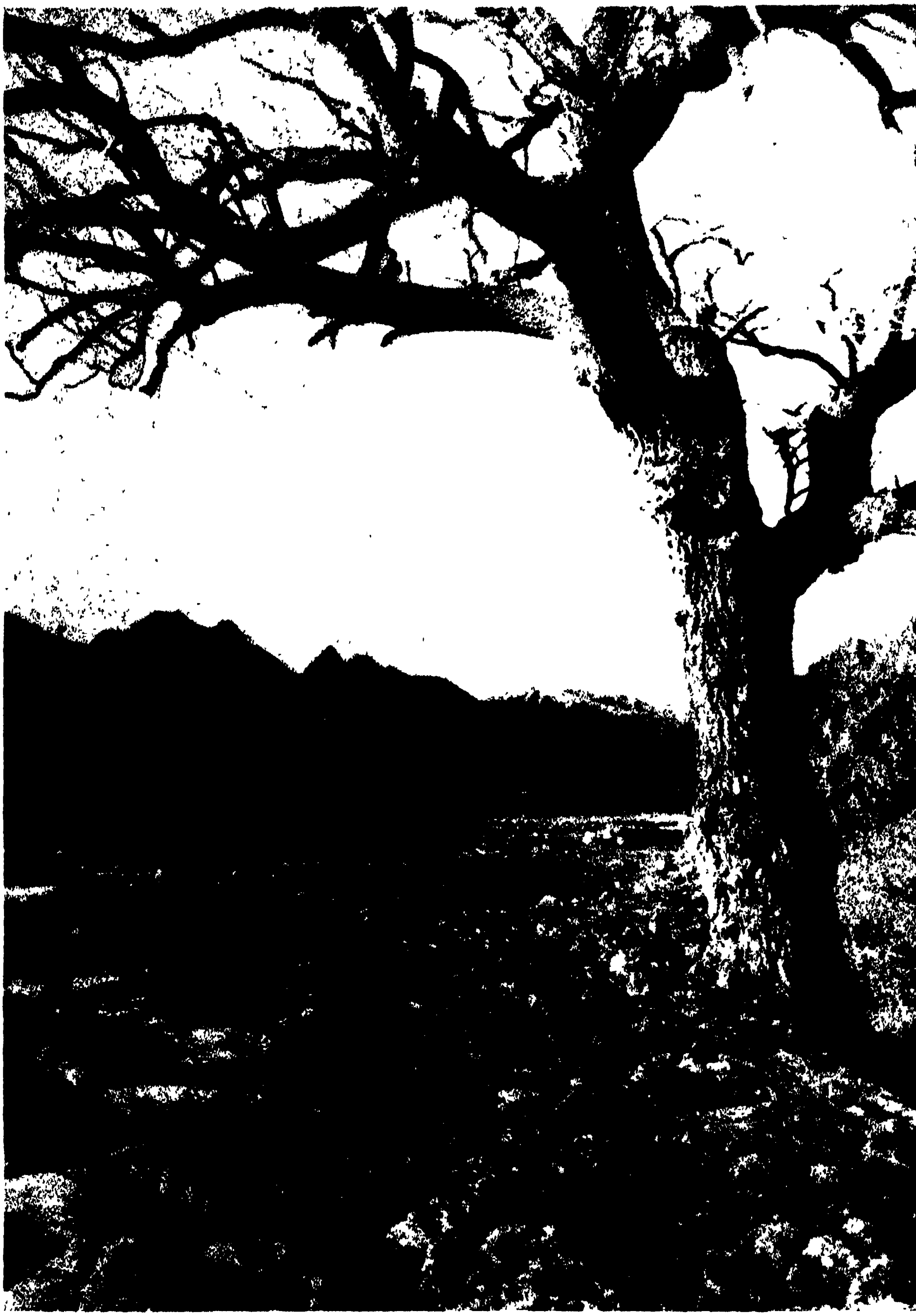
IN THE TUNG CHAI AREA. VIEW OF FORMERLY FORESTED SLOPES WHICH WERE CULTIVATED AND SERIOUSLY ERODED. TORRENTIAL RUNOFF FROM ERODING SLOPES, TO BE NOTED IN THE BACKGROUND, HAS CREATED A ROCKY, TORRENT-TORN VALLEY, AS SEEN IN THE FOREGROUND.

showed where forests had formerly stood. Here and elsewhere in Shansi were found forest remnants where temples and monasteries had protected forest areas ranging from a few to many hundreds of acres. In these forest remnants natural reproduction of the trees was taking place, showing that conditions of climate and soil were still favorable to forest growth. The gazetteer of Ning-wu Prefecture of 1750 includes a record taken from a stone monument then preserved, dated in 1684, recording successful effort in preventing the opening of certain mountains in the prefecture for the removal of trees, stated to be mostly birch, willow and others suitable for rafters, large size timber (pine) then being very scarce. It also records that in the period 1573–1620 Provincial Governor Lü K'un ordered that in all the mountain valleys along the border, trees should be planted as an obstacle to inroads of enemies on horseback, and prohibited cutting them down. But by 1750 only a few were said to remain. The advance of cultivation upon the forest was observed and reported by the senior author in 1925.[14] That the clearing of forest in this region was done mainly for the purpose of cultivating the soil was made clear by thousands of cubic feet of timber that were left to rot beside the newly cleared fields.

Experiments were made to determine the percentage of runoff, the amount of erosion, from duplicated plots in temple forests and in fields on adjacent slopes denuded by erosion. Results of these field experiments at three widely spaced centers are given in full elsewhere.[15] Out of five storms measured at the Tung Chai study area, runoff occurred during only two storms from plots in a temple forest, averaging for all storms 0.013 per cent. of total rainfall; whereas runoff occurred in all storms on plots in fields denuded by erosion, where the average was 2.27 per cent., and the greatest runoff coefficient for any one storm was 6.64 per cent. Immediate storm runoff was influenced by rate of rainfall, slope and character of the soil. This evidence readily ex-

[14] *Loc. cit.*

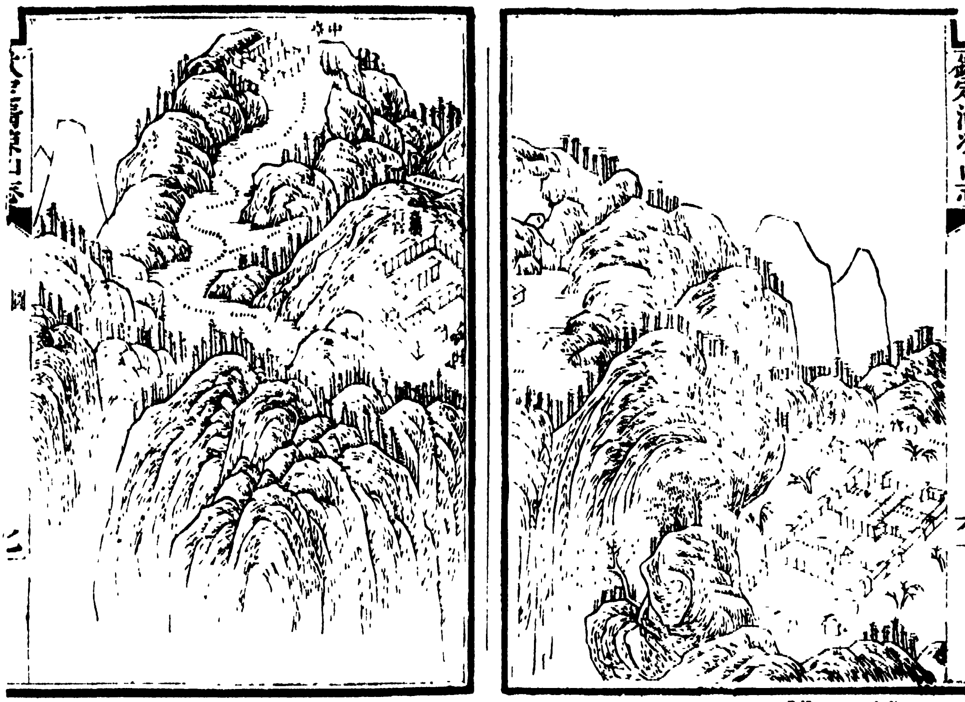
[15] Lowdermilk, W. C. Factors influencing the surface runoff of rain waters. Third Pan-Pacific Science Congress. Tokyo, 1926, pp. 2122–2148.



Bailey Willis

LOOKING UP THE AGGRADED VALLEY OF THE T'AI-SHAN HO

TO WESTERN PLATFORM OF WU-T'AI SHAN. ALLUVIAL CONE IS FROM A TRIBUTARY ON THE LEFT.



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CENTRAL PLATFORM OF WU-T'AI SHAN

FROM THE SAME GAZETTEER. NOTE CONSIDERABLE REMNANTS OF FOREST REPRESENTED.

Bailey Willis

VALLEY OF THE T'AI-SHAN HO

WITH ALLUVIAL FAN FROM A TRIBUTARY. WU-T'AI SHAN VILLAGE WITH SLOPES TERRACED TO RETAIN THE SOIL IS AT THE LEFT.

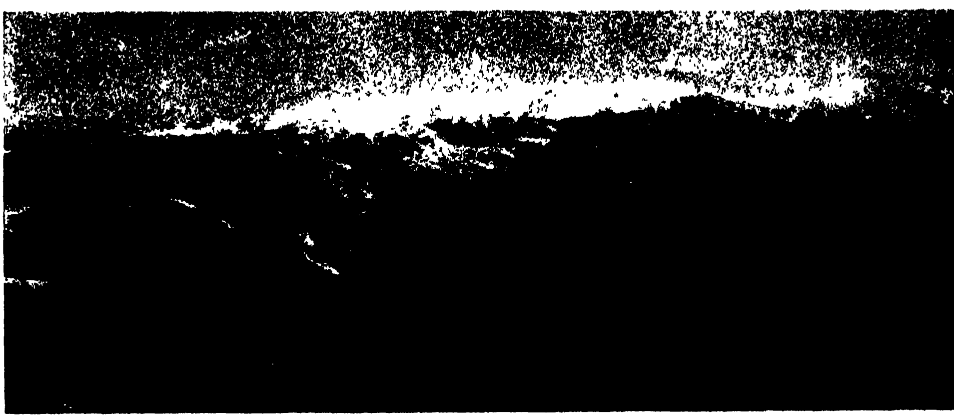
plained why cultivated slopes were yielding torrential storm runoff and were eroding into deep and destructive gullies during each rainy season, whereas no measurable erosion was taking place within temple forests, and storm runoff was very low and clear.

In the Tung Chai region, fields that had been cultivated for from 3 to 9 years varying with slope were abandoned for cultivation and thereupon herds of sheep and goats were turned out on them. Return of vegetation under heavy grazing was slow, and left the land exposed to erosion each rainy season.

We pass now to an area less than fifty miles to the east of Tung Chai, for which we made a study on the basis of unusually full records in gazetteers.[17]

THE SACRED MOUNTAIN OF WU-T'AI SHAN

The region of Wu-t'ai Shan is very mountainous, with high rounded summits and lower areas much dissected by erosion. The Hu-t'o River flows on three sides of and with its affluents drains the Wu-t'ai massif. Another mountain ridge extends along the Great Wall to the north and northwest, with the narrow plain of the Hu-t'o between. Rainfall of the summer rainy season is prevailingly convectional, but there is also some winter snowfall on the mountains.



Bailey Willis

VIEW FROM SUMMIT OF SOUTHERN PLATFORM OF WU-T'AI SHAN.
DEFORESTED SLOPES CUT WITH GULLIES COMPRISE MOST OF THE LAND SURFACE.

The gazetteer of Ning-wu Prefecture already cited has a record dated in 1750 of school and sacrificial lands that tells of decrease in income from sloping lands that became wastes. The Supplement dated in 1857 records on the first page that the Sang-kan River changed its course and washed away a hill near the East Gate of the City of Ning-wu.

Thus from observation and experiment, confirmed by a study of official records is revealed the process by which lands in this part of Shansi formerly covered with forest are cleared, cultivated, grazed, lose their productiveness and become a source of torrential floods.

Soils of the Wu-t'ai Shan region are similar to those of the Tung Chai area—being loessial on the lower flanks of the mountain and residual on the upper slopes and summits, chiefly from igneous rock. From Fig. 15 one may see how the loess occurs as drifts on the lower slopes. These soil drifts are generally sought out for farming, often terraced to save the

[17] Lowdermilk, W. C. and Wickes, D. R., History of Soil Use in the Wu T'ai Shan Area, a monograph issued under the auspices of the N. C. Branch of the Royal Asiatic Soc., 1938.

soil from erosion. Residual soils being thinner and containing rock fragments are not suited to terracing. Clearing and cultivation induces erosion that soon washes off fine soil and leaves an erosion pavement at the surface. Abandonment follows after a few years of cultivation. Accelerated runoff from eroded upper slopes has cut down through drifts of loessial soil and has washed much of it away, except where safeguarded by bench terracing.

Bailey Willis

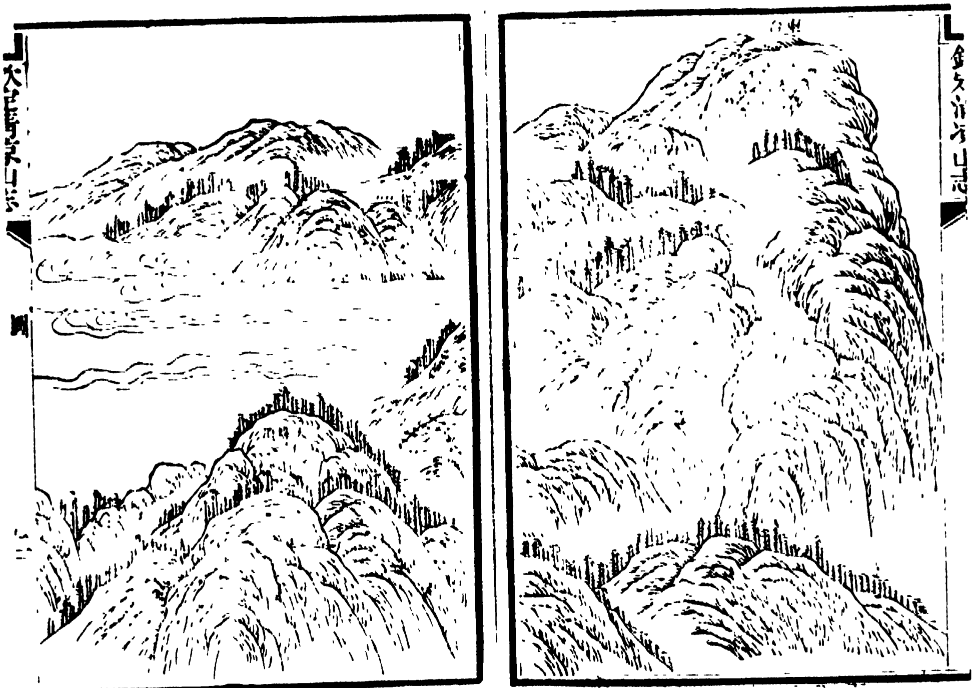
A GRAPHIC PICTURE OF THE EFFECTS OR EROSION

AS A RESULT OF DEFORESTATION AND CULTIVATION, HIGH ON THE NORTHWEST SLOPE OF WU-T'AI SHAN. SOIL HAS BEEN WASHED OFF TO BARE ROCK IN THE FOREGROUND.

Records of this area are preserved in three gazetteers of the mountain region, which covers about 800 square miles or about 500,000 acres. Likewise records exist for two districts and the department in which the mountain of "five platforms" lies. These gazetteers date from A.D. 1596, 1701, 1777, 1785, 1786, 1836, 1881, 1882, and contain much information bearing on our subject.[17]

From these records we learn that dense high forests once covered the entire region of the mountain massif including adjoining ranges, on an area estimated at 3,000 square miles, with the probable exception of the highest summits. The region was sparsely settled in the first century of the Christian era; it became a favorite retreat for those seeking retirement from the world. Numerous monasteries were founded in the seclusion of these mountains in which monks supported themselves by farming. Settlers besides the monks followed and also cleared land for cultivation, as stated by a contemporary writer about the year A.D. 1087.[18] In the early part of the Ming Dynasty, which lasted from 1368 to 1644, we are assured that the old forested condition still prevailed. By the year 1580, about 200 years later, much of this forest had been cut and sold for profit from timber. An official, Hu Lai-kung, visiting the mountain in that year was struck with the desolation he saw. As a result he had a special report made to the Throne, that led to a prohibition by the Emperor of cutting timber in these mountains. The text of this report has been preserved to us in gazetteers of

[18] Chang Shang-ying, who was at Wu-t'ai in that year. Id. p. 3.



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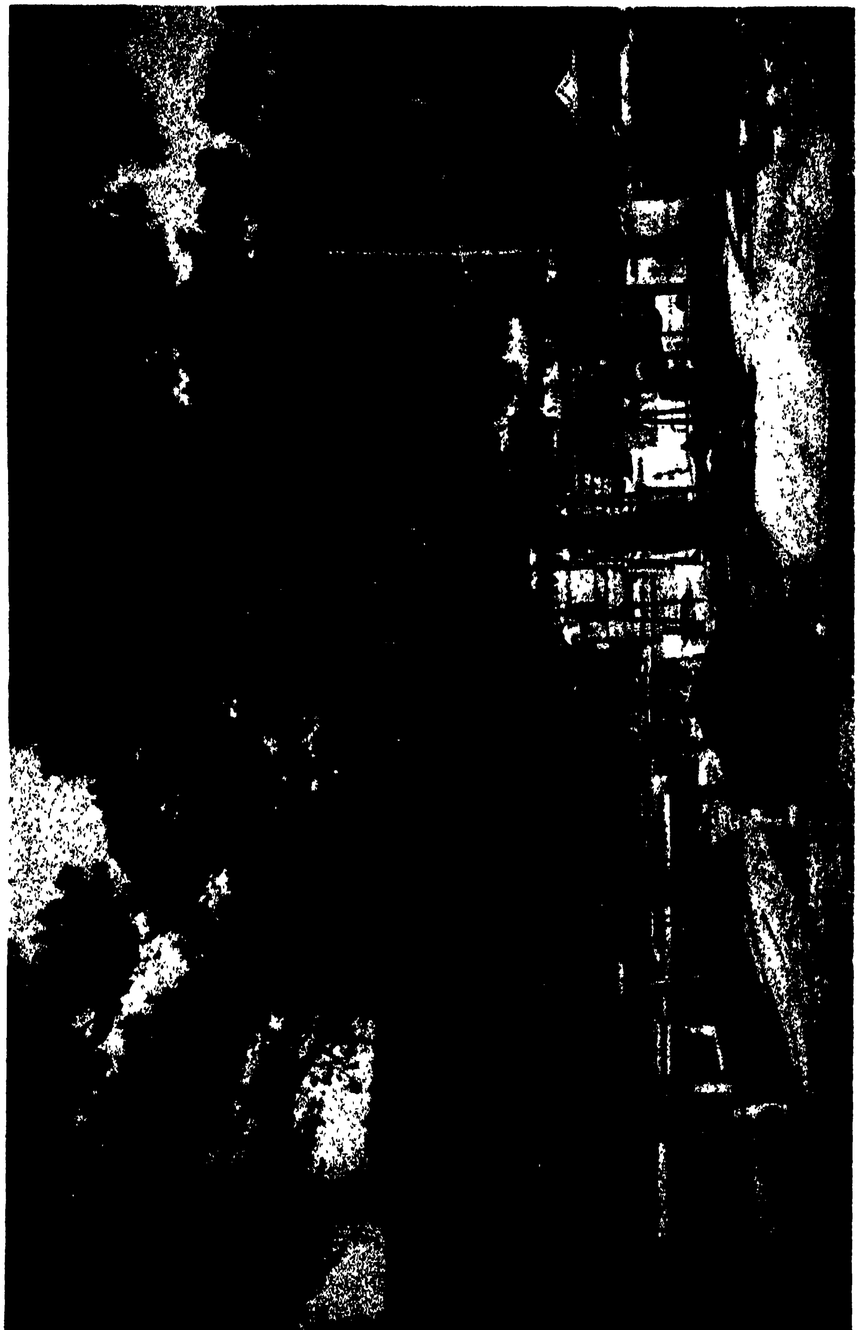
EASTERN PLATFORM OF WU-T'AI SHAN

AND ADJACENT HEIGHTS, WITH FOREST REMNANTS. FROM THE SAME GAZETTEER.

Bailey Willis

TERRACES MADE IN DRIFTS OF LOESS

FOR RETAINING SOIL ON SLOPES OF MOUNTAINS WHICH ARE BARE OF FOREST, EIGHT MILES SOUTHEAST OF WU-T'AI HSIEN. BY SUCH TERRACING THE LOESS, WHICH ALONE IS CULTIVATED, IS PROTECTED FROM EROSION.



PINES PRESERVED NEAR A MONASTERY

IN THE WU-T'AI SHAN AREA NEAR THE CLEAR WATER RIVER, ABOUT TEN MILES EAST OF THE SOUTHERN PLATFORM.

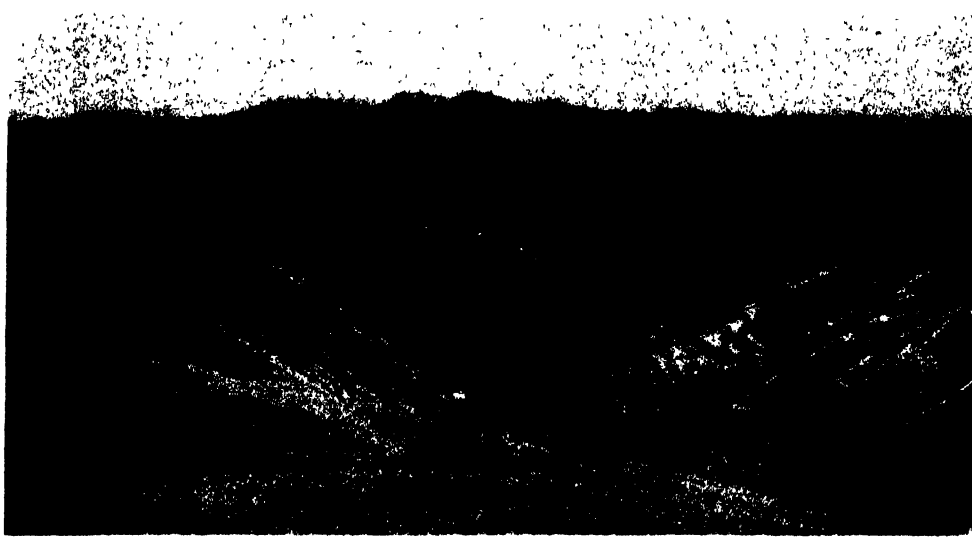
the mountain. The chief argument presented for prohibition of cutting and for preservation of the forest is that this forest was important for defense against invasions of nomads from the north. This special report of 1580 to the Throne presented by the Censor Kao Wen-chien states:

> In Shansi the border between China and the land of the barbarians is a mountain range. Fortunately, the forests between Pei-lou and Ning-wu are flourishing and thick, serving as a fortification for defense, and the mountain of Wu-t'ai with its numerous ridges and dense forests was relied on as an inner barrier. The fathers handed down the tradition which says that the trees of the two mountain ranges formerly met in green obscurity for a thousand li (330 miles) and even if the horses of the northern barbarians broke through, they could not proceed at a gallop.[19]

Methods recommended and then ordered to be carried out for the protection of forest on Wu-t'ai Shan included the driving out of unregistered wood cutters from neighboring districts, patrol of the forests day and night by monks and officials with archers to support them, arrest and speedy trial of offenders. No timber old or newly cut was allowed to be sold, the local official to be held responsible for any log reaching a river or stream. "Thus," the report concludes, "with everyone doing his duty, the national frontier will be safeguarded forever."

Recommendations of the special report were approved by the Emperor, the Board of War taking cognizance, and the proposals were authorized to be carried out. It is recorded that the cutting and logging were stopped. Not only so, but the official gazetteer of 1786 contains the statement that from the time of this prohibition of felling (about 1580) new growth gradually came back, as was to be expected if the ground was not cultivated. Other passages in the gazetteers referring to forest growth confirm this statement.

It seems clear that forests covered the area from which timber cutters had



Bailey Willis

BARED AND FORMERLY CULTIVATED MOUNTAIN SLOPES
IN THE PROCESS OF DISSECTION INTO GULLIES, WU-T'AI SHAN AREA.

[19] Lowdermilk and Wickes, History of Soil Use in the Wu T'ai Shan Area, p. 7, 1938. The idea of forests aiding defense was put forward by Ch'iu Chun, a Grand Secretary, in a work presented to the emperor in 1488. Ta-hsueh yen-i pu, ch. 150, 3a f.

Bailey Willis

FARMS IN THE PATH OF FLOODS

IN A LOESS BASIN, WU-T'AI SHAN AREA, SHOWING DEPOSITS OF DEBRIS FROM FLOODS AND WALLS BUILT BY FARMERS TO CATCH SILT TO BUILD OF NEW LAND OUT OF THE WASTE OF ERODED SLOPES.

Bailey Willis

DEFORESTED AND GULLIED SLOPES OF A CANYON

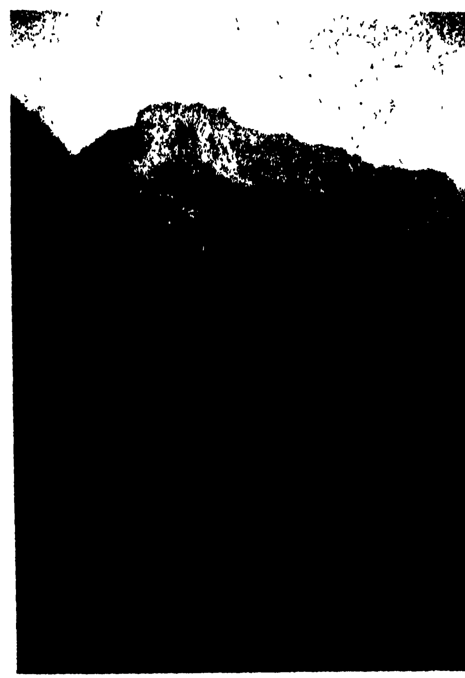
ON THE NORTH SLOPE OF WU-T'AI SHAN. TERRACES FOR CULTIVATION CAN BE SEEN HIGH ON THE SLOPES AT THE LEFT AND IN THE MIDDLE DISTANCE.

been expelled by imperial order. At the time of the first general deforestation the evidence favors the view that no general cultivation of soils took place. The official report refers to timber cutters as people without root (in the soil) who do not follow agriculture. And the refererences to the return of forests make it improbable that serious soil erosion had taken place at that period. However, from the year 1657, only seventy-seven years following the prohibition of cutting, we begin to find in the gazetteers reports of colonists of this region being encouraged to bring new land under cultivation and of additions to the cultivated area in Tai Department (including Fan-chih, Kuo, and Wu-t'ai Districts) of which these mountains occupied a considerable part. This increase of cultivation at the higher elevations in the mountains occurs probably after introductions of New World crops of Irish potatoes and maize adapted to higher altitudes than former Chinese crops.[20] The official gazetteer of Wu-t'ai Shan presented to the Emperor Ch'ien-lung in 1786, along with the statement that the mountain for a hundred years had been well wooded and green as of old, also reports progress of cultivation, stating that cultivating and planting were daily opening up more land. The gazetteer of the department for 1785 confirms wide extension of cultivation in Wu-t'ai. Between 1656 and 1759 records indicate the cultivation of a total of at least 8,560 acres previously uncultivated in the two districts which include Wu-t'ai Shan.

[20] David, A., Journal de mon troisième Voyage d'exploration dans l'empire Chinois. Vol. 1, pp. 181, 188. 1875.

Maize, known in China before 1570, was reported much grown in Shansi before 1643. B. Laufer, Congrès Intern. des Américanistes, XV. Quebec, 1907, pp. 238 f., 251. Potatoes were a later introduction, apparently by 1700, and their planting received imperial encouragement in 1752. B. Laufer, The American Plant Migration, Part I, pp. 71 f. 1938.

That destructive erosion followed the cultivation of slopes is shown by records of school lands in the gazetteer of Wu-t'ai District for 1777. It notes that certain "school fields of the District being mountain fields are changed to waste; formerly over thirty ch'ing,[21] they now are only something over two ch'ing"; and not far away 35.5 ch'ing of school fields, including a strip of lofty pine, are reported as "now abandoned."



Bailey Willis

DENUDED SLOPES
ON THE NORTHERN SIDE OF WU-T'AI SHAN.

Population figures for these districts also indicate a great increase in the number of people supported, presumably for the most part by agriculture. For the northern district, the population reported for the Ch'ien-lung period two centuries later (1736–1795) is more than fifteen times that in Chia-ching time (1553), the increase being 73,000. In the southern district the increase over

[21] A ch'ing is 100 mou, or 15.13 acres; 30 ch'ing are about 454 acres.

Bailey Willis

TREES PRESERVED BY A VILLAGE AND ITS SHRINE
WITH DENUDED MOUNTAINS AND GULLIES IN LOESS NEAR BY, IN THE WU-T'AI SHAN AREA. THE LOESS ON THE LOWER SLOPES HAS BEEN TERRACED FOR CULTIVATION; IT HAS PROBABLY BEEN WASHED OFF FROM THE STEEPER SLOPES.

about 400 years, from Ming Hung-wu time (A.D. 1368–1398) to the reign of Ch'ien-lung (1736–1795) is 77,424, making the total population reported five times as large as before. Even allowing for inaccuracies in reporting, it seems clear that a notable increase in population took place in the Wu-t'ai Shan area following this period of clearing and cultivation. Some people probably worked at coal mines, quarries, and lime kilns, which are reported in the gazetteers, and some doubtless were wood-cutters and charcoal burners.

To the destruction of forests was added the cultivation of large areas of sloping lands. A later prohibition of the cutting of mountain timber decreed in 1683 on the occasion of a visit to the Wu-t'ai Shan by the Emperor K'ang-hsi seems not to have prevented the continued clearing of land for cultivation. And by the year 1904 Bailey Willis of the U. S. Geological Survey on visiting the Sacred Mountain, recorded[22] that the forests had been completely destroyed, as E. Licent also reported[23] in 1914. A few monasteries still preserved groves about them, and under the summits scattered pine trees still grew on the slopes. Horse dung was burned for heating in all the region for want of fuel wood. Crops of potatoes, an introduction from the Western Hemisphere, and hemp were raised. High summits bore cultivated fields on their slopes. By this time slopes and ravine bottoms of the massif of Wu-t'ai were absolutely denuded by wood cutters and herders. Southwest of the Wu-t'ai massif, between it and the city of Wu-t'ai Hsien, he reported the medium heights entirely denuded, and southwest of the city he again speaks of black, denuded mountains.[23]

Both Willis and Licent tell of great alluvial cones of shingle, gravel and clay, the wash of rock and residual soil on the mountain slopes, such as the Senior au-

[22] Willis, Bailey, *et al.* Research in China, 1907, Vol. I, p. 209.

[23] Licent, E. Comptes Rendus de Dix Années (1914–1923) de Séjour et d'Exploration dans le Bassin du Fleuve Jaune . . . 1924, pp. 1466, 1467, 1461.

Bailey Willis

ERODED LOESS AND DEPOSITED DETRITUS

AT THE FOOT OF BARE MOUNTAINS, EIGHTEEN MILES NORTHEAST OF WU-T'AI HSIEN AND FIVE MILES WEST OF THE SOUTHERN PLATFORM. DRIFTS OF LOESS HAVE PERSISTED ON THE GENTLER SLOPES OF THE MOUNTAINS; IT HAS DOUBTLESS BEEN WASHED OFF STEEPER SLOPES.

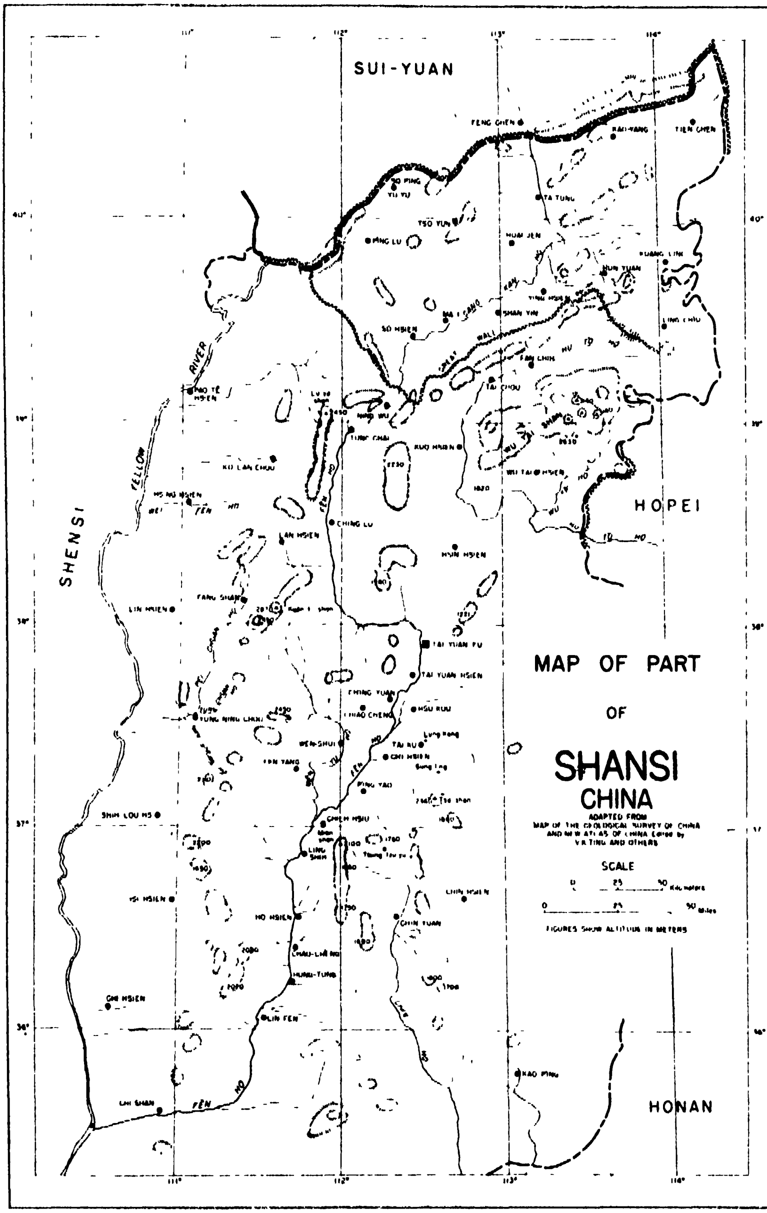
thor also recorded in the Tung Chai area just to the West. Emil S. Fischer, who visited the mountains in 1923 reported,[24] besides the general bareness of trees, extensive grazing over the mountain range, "herds of sheep, horses, cattle and goats at times over 500 heads strong, grazing on the slopes"; also "numerous camel herds grazing as well as hundreds of horses." At one place he reports that "the men were to be seen toiling on the mountain sides wherever there was a spot that permitted cultivation." Cutting of forests followed by erosion of cultivated fields had denuded the Sacred Mountain of Wu-t'ai shan.

Records of Floods from Ancient Times

As early as the 4th year of T'ai-ting, in A.D. 1327 (the Yuan Dynasty) we find a record of destructive floods in the Hu-t'o River, which carries most of the drainage from Wu-t'ai Shan, flowing around the mountain group on three sides and eastward into Hopei Province, and at Hsien Hsien unites with the Chin-yang River to form the Tzu-ya River, a tributary of the Hai Ho that flows by Tientsin. In the period from A.D. 1056 to 1063 (Chia-yu hsi-ning time of the Sung Dynasty) a western tributary of the Hu-t'o, the Yang-wu River, is stated in the local gazetteer to have frequently ruined cultivated land along its banks by its floods, so that some land was abandoned.

In a later period it is recorded in the gazetteer of Fan-chih District, which includes the northern part of Wu-t'ai Shan (1836), "mountain streams often overflow, quickly swell and quickly dry up"; and of irrigation canals of the Hu-t'o River the same gazetteer says: "The water of this river is rapid from its source to where it leaves the district; and when the fierce overflow of mountain streams occurs, it no sooner swells than it dries up." A torrential regime of

[24] Fischer, E. S., Jour. of the N. China Branch of the Royal Asiatic Soc. Vol. 54 (1923) pp. 81–113.



flooding and drying up is indicated in other statements of the same gazetteer. This river also repeatedly changed its course, owing to deposits of erosion debris in its channel, as did its tributaries. Irrigation was thus made precarious, and great damage was done to agricultural land and settlements.

Land is Ruined and Abandoned

Again and again from A.D. 1647 on, we find records of the acreage of lands exempted from taxation as waste or abandoned; of these some are doubtless due to losses of soil by erosion and some to ruin by the overflow of streams. In the 4th year of Shun-chih (1647) an edict ex-

empted 5,189 acres (343 ch'ing) of ownerless deserted land. In 1657 another edict exempted a total of 34,870 acres of deserted land of the Fan-chih district, of which 13,186 acres were agricultural land of civilians. Abandoned land was characterized as "injured and perished"; 20,877 acres were deserted land of military colonists. In Wu-t'ai District in 1657, 16,806 acres of injured and destroyed waste land of civilian owners were exempted by edict. Remaining land actually cultivated was only 22,-809 acres (1,507.5 ch'ing, of which 4.5 ch'ing are listed as water land, 316.6 as level land, 879.7 as slope land, and 306.6 as sandy land). In 1652 there were exempted 358 acres of deserted land of military colonists. In Tai Department[25] adjoining Fan-chih District on the west, it is recorded that at various times from 1785 (50th year of Ch'ien-lung) to 1879 (5th year of Kuang-hsu) there were removed from the tax list deserted agricultural lands of civilians and colonists to the amount of about 15,465 acres, nearly one sixth of the total taxable land. In 1880 land in the neighborhood of Shê-ying, long deserted on account of a flood in 1785 which deposited stones and deep sand upon it or washed it away, to the total of about 1,189 acres was permanently released from taxation. In Kuo District, on the west side of Wu-t'ai Shan, in 1787, 1803, and 1880 a total of about 2,236 acres found by investigation to have been swallowed up by the river, ruined by erosion, or covered with stones, were exempted by edict from taxation.

Thus a large mountainous area formerly forested, despite repeated and for a time apparently successful efforts to conserve forests, was cleared of timber and largely cultivated, with consequent destructive erosion. Abandonment of land for cultivation totaled nearly 75,000 acres;[26] violent and destructive floods and changes in their courses on the part of drainage streams also followed.

The Districts of Hun-yuan and Ling-ch'iu adjoin this area on the northeast, and their records reveal similar conditions. One gazetteer dated in 1652 states that a magistrate in the period of Ch'eng-hua, 1465–1487, secured the relaxing of a former prohibition of cutting or gathering firewood on Heng Shan Mountain, south of the city of Hun-yuan, that reveals an early measure for protection of forests. Toward the north and west of these districts extended Ta-t'ung and So-p'ing Prefectures, which have records of former forests with remnants on mountains, of extensive colonization, of the abandonment of large quantities of land formerly cultivated, and of torrential floods and shifts in stream courses.

A supplementary gazetteer issued in 1881, in a record of the virtuous government of Yen Ch'ing-Yun the magistrate of Hun-yuan Department in 1771–1782, tells of his introducing potatoes (Irish) from Shensi, his native province, and of extensive plantings with great success in keeping great numbers of people alive during famines of 1787, 1832 and 1836. Growing of potatoes and maize may have been the occasion for cultivating so much of the forested soils of the higher slopes that induced destructive erosion and torrential debris-laden storm runoff.

25 Exclusive of Wu t'ai, Fan-chih and Kuo Districts.

26 Lowdermilk and Wickes, History of Soil Use in Wu T'ai Shan Area, p. 23.

(To be Concluded)

GREGOR MENDEL AND HIS WORK

By Dr. HUGO ILTIS
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It is 120 years since, in a small village on the northern border of what was called Austria at that time, a boy was born in a farmer's house who was destined to influence human thoughts and science. Germans, Czechs and Poles had been settled side by side in this part of the country, quarreling sometimes, but mixing their blood continually. During the Middle Ages the Mongolic Tatars invaded Europe just there. Thus, the place had been a melting pot of nations and races and, like America, had brought up finally a splendid alloy. The father's name was Anton Mendel; the boy was christened Johann. He grew up like other farmers' boys; he liked to help his father with his fruit trees and bees and retained from these early experiences his fondness for gardening and bee-keeping until his last years. Since his parents, although not poor compared with the neighbors, had no liquid resources, the young and gifted boy had to fight his way through high school and junior college (Gymnasium). Finally he came to the conclusion, as he wrote in his autobiography, "That it had become impossible for him to continue such strenuous exertions. It was incumbent on him to enter a profession in which he would be spared perpetual anxiety about a means of livelihood. His private circumstances determined his choice of profession." So he entered as a novice the rich and beautiful monastery of the Augustinians of Bruenn in 1843 and assumed the monastic name of Gregor. Here he found the necessary means, leisure and good company. Here during the period from 1843 to 1865 he grew to become the great investigator whose name is known to every schoolboy to-day.

On a clear cold evening in February, 1865, several men were walking through the streets of Bruenn towards the modern school, a big building still new. One of those men, stocky and rather corpulent, friendly of countenance, with a high forehead and piercing blue eyes, wearing a tall hat, a long black coat and trousers tucked in top boots, was carrying a manuscript under his arm. This was Pater Gregor Mendel, a professor at the modern school, and with his friends he was going to a meeting of the Society of Natural Science where he was to read a paper on "Experiments in Plant Hybridization." In the schoolroom, where the meeting was to be held, about forty persons had gathered, many of them able or even outstanding scientists. For about one hour Mendel read from his manuscript an account of the results of his experiments in hybridization of the edible pea, which had occupied him during the preceding eight years.

Mendel's predecessors failed in their experiments on heredity because they directed their attention to the behavior of the type of the species or races as a whole, instead of contenting themselves with one or two clear-cut characters. The new thing about Mendel's method was that he had confined himself to studying the effects of hybridization upon single particular characters, and that he didn't take, as his predecessors had done, only a summary view upon a whole generation of hybrids, but examined each individual plant separately.

The experiments, the laws derived from these experiments, and the splendid explanation given to them by Mendel are to-day not only the base of the modern science of genetics, but belong to the

PORTRAIT OF GREGOR MENDEL BY JOSEPH O. FLATTER[1]

fundamentals of biology taught to millions of students in all parts of the world.

Mendel had been since 1843 one of the brethren of the beautiful and wealthy monastery of the Augustinians of Bruenn, at that time in Austria, later in Czechoslovakia. His profession left him sufficient time, and the large garden of the monastery provided space enough, for his plant hybridizations. During the eight years from 1856 to 1864, he observed with a rare patience and perseverance more than 10,000 specimens.

[1] I am indebted to Professor William Luther McDermott for the photographs in this article.

In hybridization the pollen from the male plant is dusted on the pistils of the female plant through which it fertilizes the ovules. Both the pollen and the ovules in the pistils carry hereditary characters which may be alike in the two parents or partly or entirely different. The peas used by Mendel for hybridization differed in the simplest case only by one character or, better still, by a pair of characters; for instance, by the color of the flowers, which was red on one parental plant and white on the other; or by the shape of the seeds, which were smooth in one case and wrinkled in the

MENDEL'S BIRTHPLACE IN HEINZENDORF, AUSTRIA

other; or by the color of the cotyledons, which were yellow in one pea and green in the other, etc. Mendel's experiments show in all cases the result that all individuals of the first generation of hybrids, the F_1 generation as it is called to-day, are uniform in appearance, and that moreover only one of the two parental characters, the stronger or the dominant one, is shown. That means, for instance, that the red color of the flowers, the smooth shape of the seeds or the yellow color of the cotyledons is in evidence while the other, or recessive, character seems to have disappeared. From the behavior of the hybrids of the F_1 generation, Mendel derived the first of the experimental laws, the so-called "Law of Uniformity," which is that all individuals of the first hybrid generation are equal or uniform. The special kind of inheritance shown by the prevalence of the dominant characters in the first hybrid generation is called alternative inheritance or the pea type of inheritance. In other instances, however, the hybrids show a mixture of the parental characteristics. Thus, crossing between a red-flowered and a white-flowered four o'clock (*Mirabilis*) gives a pink-flowered F_1 generation. This type of inheritance is called the intermediate, or Mirabilis, type of inheritance.

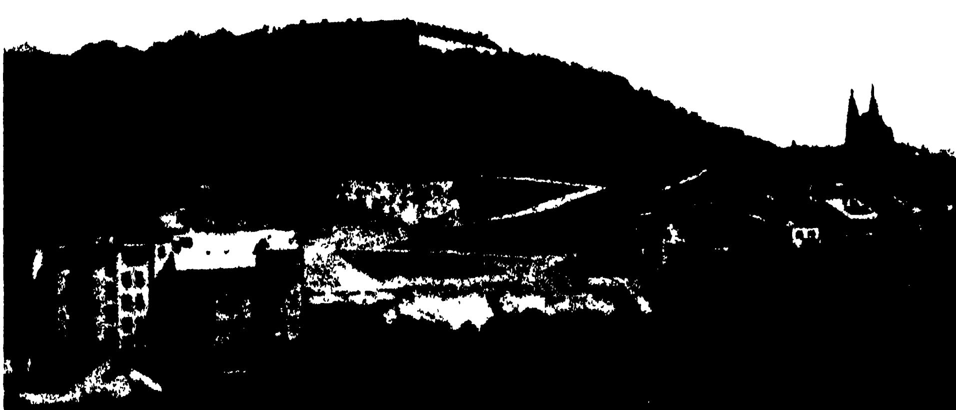
Now, Mendel self-fertilized the hybrids of the first generation, dusting the pistils of the flowers with their own pollen and obtained thus the second, or F_2, generation of hybrids. In this generation the recessive characters, which had seemingly disappeared, but, which were really only covered in the F_1 generation, reappeared again and in a characteristic and constant proportion. Among the F_2 hybrids he found three red-flowered plants and one white-flowered plant, or three smooth-seeded and one-wrinkled-seeded plant, or three plants with yellow cotyledons and one with green ones. In general, the hybrids of the F_2 generation showed a ratio of three dominant to one recessive plants. Mendel derived from the behavior of the F_2 generation his second experimental law, the so-called "Law of Segregation." Of course, the characteristic ratio of three dominant to one recessive may be expected only if the numbers of individuals are large, the Mendelian laws being so-called statistical laws or laws valid for large numbers only.

The third important experimental law Mendel discovered by crossing two plants which distinguished themselves not only by one but by two or more pairs of hereditary characters. He crossed, for instance, a pea plant with smooth and yellow seeds with another having green and wrinkled seeds. The first, or F_1,

generation of hybrids was of course uniform, showing both smooth and yellow seeds, the dominant characters. F_1 hybrids were then self-fertilized and the second hybrid, or F_2, generation was yielded in large numbers, showing all possible combinations of the parental characters in characteristic ratios and that there were nine smooth yellow to three smooth green to three wrinkled yellow to one wrinkled green. From these so-called polyhybrid crossings, Mendel derived the third and last of his experimental laws, the "Law of Independent Assortment."

These experiments and observations Mendel reviewed in his lecture. Mendel's hearers, who were personally attached to the lecturer as well as appreciating him for his original observations in various fields of natural science, listened with respect but also with astonishment to his account of the invariable numerical ratios among the hybrids, unheard of in those days. Mendel concluded his first lecture and announced a second one at the next month's meeting and promised he would give them the theory he had elaborated in order to explain the behavior of the hybrids.

There was a goodly audience, once more, at the next month's meeting. It must be admitted, however, that the attention of most of the hearers was inclined to wander when the lecturer became engaged in a rather difficult algebraical deduction. And probably not a soul among the audience really understood what Mendel was driving at. His main idea was that the living individual might be regarded as composed of distinct hereditary characters, which are transmitted by distinct invisible hereditary factors—to-day we call them genes. In the hybrid the different parental genes are combined. But when the sex cells of the hybrids are formed the two parental genes separate again, remaining quite unchanged and pure, each sex cell containing only one of the two genes of one pair. We call this fundamental theoretical law the "Law of the Purity of the Gametes." Through combination of the different kinds of sex cells, which



BRUENN, CZECHOSLOVAKIA, WHERE MENDEL LIVED

BRUENN IS SITUATED BELOW THE SPIELBERG, WITH ITS FORTRESS, AND THE PETERSBERG, WITH ITS GOTHIC DOME. IT IS NOW A TOWN OF MORE THAN 300,000 INHABITANTS, FOR THE MOST PART CZECHS AND KNOWN BY THE CZECH NAME BRNO.

MONASTERY AND CHURCH OF THE ORDER OF THE AUGUSTINS
HANS MENDEL ENTERED THIS MONASTERY IN 1843 AND RECEIVED THE MONASTIC NAME OF GREGOR. THE OLD CONVENT CHURCH IS FOURTEENTH CENTURY GOTHIC OF DARK RED BRICK.

are produced by the hybrid, the law of segregation and the law of independent assortment can be easily explained.

Just as the chemist thinks of the most complicated compound as being built from a relatively small number of invariable atoms, so Mendel regarded the species as a mosaic of genes, the atoms of living organisms. It was no more nor less than an atomistic theory of the organic world which was developed before the astonished audience. The minutes of the meeting inform us that there were neither questions nor discussions. The audience dispersed and ceased to think about the matter—Mendel was disappointed but not discouraged. In all his modesty he knew that by his discoveries a new way into the unknown realm of science had been opened. "My time will come," he said to his friend Niessl.

Mendel's paper was published in the proceedings of the society for 1866. Mendel sent the separate prints to Carl Naegeli in Munich, one of the outstanding biologists of those days, who occupied himself with experiments on plant hybridization. A correspondence developed and letters and views were exchanged between the two men. But even Naegeli didn't apreciate the importance of Mendel's discovery. In not one of his books or papers dealing with heredity did he even mention Mendel's name. So, the man and the work were forgotten.

When Mendel died in 1884, hundreds of mourners, his pupils, who remembered their beloved teacher, and the poor, to whom he had been always kind, attended the funeral. But although hundreds realized that they had lost a good friend, and other hundreds attended the funeral of a high dignitary, not a single one of those present recognized that a great scientist and investigator had passed away.

The story of the rediscovery and the sudden resurrection of Mendel's work is

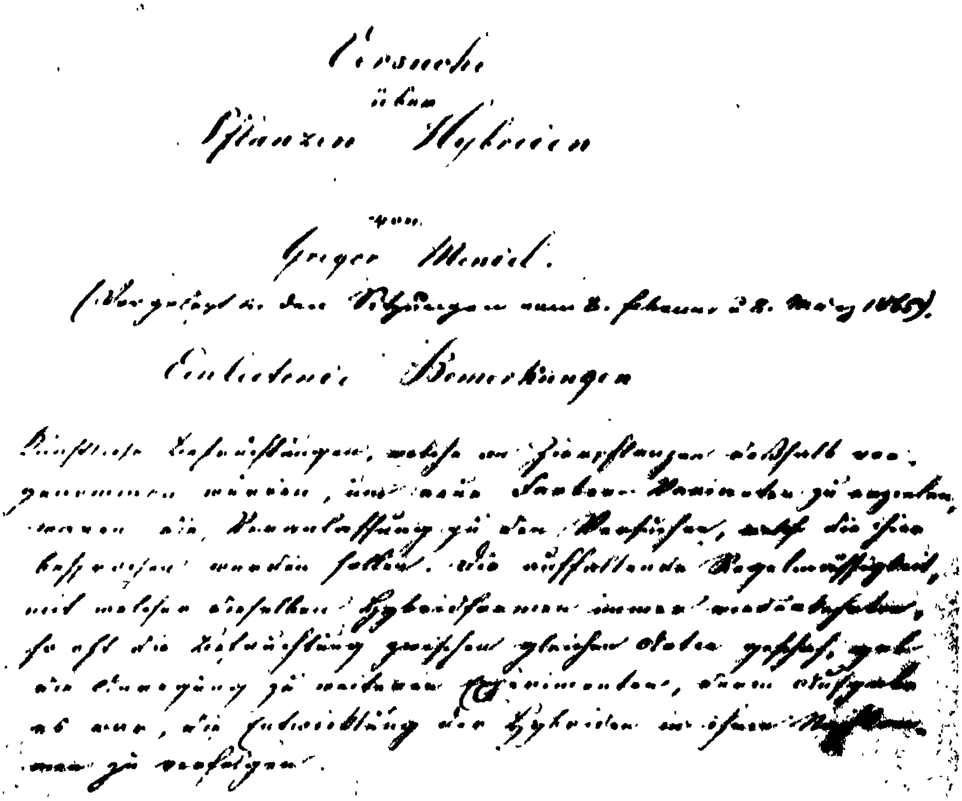
a thrilling one. By a peculiar, but by no means an accidental, coincidence three investigators in three different places in Europe, DeVries in Amsterdam, Correns in Germany, Tschermak in Vienna, came almost at the same time across Mendel's paper and recognized at once its great importance.

Now the time had arrived for understanding, now "his time had come" and to an extent far beyond anything of which Mendel had dreamed. The little essay, published in the great volume of the Bruenn Society, has given stimulus to all branches of biology. The progress of research since the beginning of the century has built for Mendel a monument more durable and more imposing than any monument of marble, because not only has "Mendelism" become the name of a whole vast province of investigation, but all living creatures which follow "Mendelian" laws in the hereditary transmission of their characters are said to "Mendelize."

As illustrations, I will explain the practical consequences of Mendelian research by two examples only. The Swede, Nilsson-Ehle, was one of the first investigators who tried to use Mendelistic methods to improve agricultural plants. In the cold climate of Sweden some wheat varieties, like the English square-hood wheat, were yielding well but were frozen easily. Other varieties, like the Swedish country wheat, were winter-hard but brought only a poor harvest. Nilsson-Ehle knew that in accordance with the Mendelian law of independent assortment, the breeder is able

MENDEL'S BEEHOUSE IN THE GARDEN OF THE MONASTERY
AT TIMES, THIS APIARY HELD MORE THAN FIFTY SWARMS OF BEES.

to combine the desired characters of two different parents, like the chemist who combines the atoms to form various molecules or compounds. He crossed the late-ripening, well-yielding, square-hood wheat with the early-ripening, winter-hard, but poor-yielding Swedish country wheat. The resulting F_1 generation, however, was very discouraging. It was uniform, in accordance with Mendel's first law, all individuals being late-ripe and poor-yielding, thus combining the two undesirable dominant characters. In pre-Mendelian times the breeder would have been discouraged and probably would have discontinued his efforts. Not so Nilsson-Ehle, who knew that the F_1 generation is hybrid, showing only the dominant traits, and that the independent assortment of all characters will appear only in the F_2 generation. Self-fertilizing the F_1 plants he obtained an F_2 generation showing the ratio of nine late-ripe poor-yielding to three late-ripe well-yielding, to three early-ripe poor-yielding, to one early-ripe, well-yielding wheat plants. The desired combination of the two recessive characters, early-ripe, well-yielding, appeared only in the smallest ratio, one in sixteen--but because recessives are always true-breeding, or as it is called "homozygote," Nilsson-Ehle had only to isolate these plants and to destroy all others in order to obtain a new true breeding early-ripe and well-yielding variety which after a few years gave a crop large enough to be sold. Thus, by the work of the Mendel-


Versuche über Pflanzen-Hybriden von Gregor Mendel.

(Vorgelegt in den Sitzungen vom 8. Februar und 8. März 1865.)

Einleitende Bemerkungen.

Künstliche Befruchtungen, welche an Zierpflanzen deshalb vorgenommen wurden, um neue Farben-Varianten zu erzielen, waren die Veranlassung zu den Versuchen, die hier besprochen werden sollen. Die auffallende Regelmässigkeit, mit welcher dieselben Hybridformen immer wiederkehrten, so oft die Befruchtung zwischen gleichen Arten geschah, gab die Anregung zu weiteren Experimenten, deren Aufgabe es war, die Entwicklung der Hybriden in ihren Nachkommen zu verfolgen.

PART OF THE FIRST PAGE OF MENDEL'S FAMOUS PAPER

ist, Nilsson-Ehle, culture of wheat was made possible even in the northern parts of Sweden and large amounts heretofore spent for imported wheat could be saved.

Another instance shows the importance of Mendelism for the understanding of human inheritance. Very soon after the rediscovery of Mendel's paper it became evident that the laws found by Mendel with his peas are valid also for animals and for human beings. Of course, the study of the laws of human heredity is limited and rendered more difficult by several obstacles. We can't make experiments with human beings. The laws of Mendel are statistical laws based upon large numbers of offspring, while the number of children in human families is generally small. But in spite of these difficulties it was found very soon that human characters are inherited in the same manner as the characters of the pea. We know, for instance, that the dark color of the iris of the eye is dominant, the light blue color recessive. I remember a tragi-comic accident connected with this fact. At one of my lecture tours in a small town in Czechoslovakia, I spoke about the heredity of eye color in men and concluded that, while two dark-eyed parents may be hybrids in regard to eye color and thus may have children both with dark and blue eyes, the character blue-eyed, being recessive, is always pure. Hence two blue-eyed parents will have only blue-eyed children. A few months later I learned that a divorce had taken place in that small town. I was surprised and resolved to be very careful even with scientifically proved statements in the future.

Even more important is the Mendelian analysis of hereditary diseases. If we learn that the predisposition to a certain disease is inherited through a dominant gene, as diabetes, for instance, then we know that all persons carrying the gene will be sick. In this case all carriers can be easily recognized. In the case of recessive diseases, feeblemindedness, for instance, we know that the recessive gene may be covered by the dominant gene

MENDEL MUSEUM
IN THE AUGUSTIN MONASTERY HE ATTENDED.

MENDEL MEMORIAL IN BRUENN
ERECTED BY "FRIENDS OF SCIENCE" IN 1910.

for health and that the person, seemingly healthy, may carry the disease and transmit it to his children.

With every year the influence of Mendel's modest work became more widespread. The theoretical explanation given by Mendel was based upon the hypothesis of a mechanism for the distribution and combination of the genes. To-day we know that exactly such a mechanism, as was seen by the prophetic eye of Mendel, exists in the chromosome apparatus of the nucleus of the cells. The development of research on chromosomes, from the observations of the chromosomes and their distribution by mitosis to the discovery of the reduction of the number of chromosomes in building the sex cells and finally to the audacious attempt to locate the single genes within the chromosomes, is all a story, exciting as a novel and at the same time one of the most grandiose chapters in the history of science. A tiny animal, the fruit-fly, Drosophila, was found to be the best object for genetical research. The parallelism between the behavior of the chromosomes and the mechanism of Mendelian inheritance was studied by hundreds of scientists, who were trying to determine even the location of the different genes within the different chromosomes and who started to devise so-called chromosome maps.

Correns, Baur and Goldschmidt in Germany; Bateson and his school in England; DeVries in Holland; Nilsson-Ehle in Sweden, are the outstanding geneticists of the first decade after 1900. But soon the picture changed. The Carnegie Institution for Genetic Research in Long Island, under the leadership of Davenport and later under Blakeslee, became one of the world's centers of genetic research. In 1910, T. H. Morgan, then at Columbia University, later at the California Institute of Technology, started his investigations with the fruit-fly, Dro-

THE FAMOUS EXPERIMENTAL GARDEN

IN THIS SMALL PLOT, ONLY ABOUT ONE HUNDRED-AND-TWENTY FEET LONG AND TWENTY FEET WIDE, MENDEL CONDUCTED HIS EXPERIMENTS ON PLANT GENETICS, USUALLY WORKING WITH PEA PLANTS.

sophila, and founded the largest and most active school of geneticists. The U. S. Department of Agriculture with its network of experimental stations connected with more than a hundred agricultural colleges became the most admirable organization for breeding of better crops and farm animals based upon the principles of Mendelism. The ideas developed by Mendel have found a new home here in the new world.

From 1905 to 1910, I tried by lectures and by articles to renew the memory of Mendel in my home country and to explain the importance of Mendelism to the people. This was not always an easy task. Once I happened to be standing beside two old citizens of Bruenn, who were chatting before a picture of Mendel in a book-seller's window. "Who is that chap, Mendel, they are always talking about now?" asked one of them. "Don't you know?" replied the second. "It's the fellow who left the town of Bruenn an inheritance!" In the brain of the worthy man the term "heredity" had no meaning, but he understood well enough the sense of an inheritance or bequest.

SCIENCE AND WAR

It is usually assumed that modern science, which produced long-range artillery and the bursting bomb, flame-throwers and poison gas, tanks and, above all, the airplane, has made war more horrible than it was in the past. In a sense it has. There is no doubt that the impact of mechanized warfare on the individual soldier's psychology is far more terrifying and requires greater moral and physical stamina to withstand than ever before. And the airplane, which has wiped out distances, has carried the war right to the home front, and slaughters not only soldiers but also women, and children, and the aged.

And yet, in the words of Major General Vandegrift, who speaks from his experience as commander of our Marines on Guadalcanal, modern science has also made war more humane. For the quick death suffered by those killed in battle or in air raids is not the worst of war's horrors. Far more terrible even than death in the wars of the past was the agony of the wounded left to die, and the usual accompaniment of war—famine and disease, which struck behind the fronts as well with even greater force than the airplane to-day. So completely were they linked with war in popular consciousness, and so helpless did the world feel about them, that they are among the Four Horsemen of the Apocalypse. And not till modern science began to demonstrate that they were not inevitable was there an outcry against them—during the Crimean War, which produced Florence Nightingale.

To-day two of the sinister horsemen have been well-nigh eliminated. According to the latest figures, only 1 per cent. of those wounded on Guadalcanal have died, and even in Russia the death rate among the wounded is said to be only 1.5 per cent. And except for the deliberate starvation and its consequences imposed on Europe by the Nazis, famine has been beaten in the civilized parts of the world. The reasons for the first miracle are quick transportation and hospitalization of the wounded, and modern medical treatment with blood plasma and the sulfa drugs, which prevent infections and promote quick healing.—From an editorial in *The New York Times*.

THE ORIGIN OF SUPERIOR MEN[1]

By DR. E. L. THORNDIKE

EMERITUS PROFESSOR OF EDUCATIONAL PSYCHOLOGY, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

THE forty-eight states show noteworthy differences in the frequency of births of superior men. The number of persons recorded in "Who's Who in America" (1938–1939) per ten thousand of the population in 1880 is as shown in Column 1 of Table I. Massachusetts and Connecticut have over five times as many as Louisiana, Mississippi or New Mexico. If the number of women aged 20–44 in 1880 is used as a base, the differences are greater. If the white population of 1880 is used as a base, the differences, though reduced, remain substantial as shown in Column 4 of Table I. Massachusetts, Connecticut and the Northwestern States still show rates two or three times as high as those for some of the Southern States. If the populations at 1870 and 1880 and 1890, or any reasonably weighted average of the populations at 1860, 1870, 1880, 1890, and 1900 is used as a base, wide differences remain.

The persons listed in Cattell's "American Men of Science" (1938) represent a narrower field of superiority with a wider selection within that field. The births per ten thousand of the 1890 population are shown in Column 2 of Table I. The differences among states are of about the same magnitude as in the case of Who's Who men, and the rank order of the states is much like that in the case of Who's Who men. The use of the 1880 population, or the 1900 population, or any reasonably weighted average of the population from 1860 to 1910 would leave the general fact of great variation unaltered. Using the white population of 1890 as the base, we have the facts in Column 5 of Table I.

[1] This study was made possible by financial assistance from the Carnegie Corporation.

The persons who are listed in Cattell's "Leaders in Education" (1932), but are not listed in "Who's Who" for 1938–1939 (including its references to former entries) or in "American Men of Science" (1938), form a group of men and women much above the average in intelligence, achievement, and public and private virtues, though not on the average so able as the group in "Who's Who." The numbers for each state per hundred thousand of the state's 1880 population, total and white, are shown in Columns 3 and 6 of Table I.[2]

[2] Inclusion in "Who's Who" is evidence of ability and, though perhaps to a less degree, of service to the nation and world. But the data, as between states, are not strictly comparable. Of a dozen persons of equal achievement, those living in "superior" states are less likely to be included, because what may be called the *ex officio* entries in "Who's Who" (congressmen, professors in state universities and the like) are to some extent selected by geography as well as by merit. The influence of this defect is reduced in our results because only about a third of the famous persons of a state were born in it. But it is not reduced very much, since many more of them were born in that state than in an equally populated fraction of the other forty-seven states. It is also probable that ability in law, engineering, medicine, manufacturing and business is underweighted in comparison with ability in teaching, the ministry, government and public administration. Better evidence in some respects concerning the migration of the able and good is furnished by the facts for men of science presented in Cattell's "American Men of Science." The selection here is objective and impartial, it reaches down to younger ages, and less exalted levels of ability. Reputable men of science are far above the average in intellect, and somewhat above it in esthetic abilities. They rank high in both private and public morality. In business enterprise, worldly wisdom and energy they rank probably above the average teacher and clergyman, but below engineers and lawyers. By any reasonable criterion they would be placed in the top tenth of the population.

The facts of Table I are presented as samples of superior birth rates, not as authoritative measures. They favor states which had specially small populations in 1880 (or 1890 in the case of the "American Men of Science").[3]

The ratios of names appearing in the directories used to populations at any one time (which we shall call superior-birth rates) will be more or less unjust to individual states, favoring in general those which had smaller populations relatively at the time used by us than over the whole period during which the persons enrolled were born. Their birth-years are approximately as shown in Table II.

A better single measure for persons in "Who's Who" and for persons in "Leaders in Education" not in "Who's Who" or "American Men of Science" is obtained by dividing by the sum of the populations for 1870, 1880 and 1890. Four-fifths of the persons in "Who's Who" (38–39 edition) were born between 1865 and 1894, as were those in "Leaders in Education." Nearly three-fifths of those listed in "American Men of Science" were born between 1885 and

TABLE I

SAMPLE BIRTH-RATES OF SUPERIOR MEN AND WOMEN FOR EACH STATE

Column 1: Number in "Who's Who" per 10,000 population in 1880; Column 2: Number in "American Men of Science" per 10,000 population in 1890; Column 3: Number in "Leaders in Education" per 100,000 population in 1880, excluding any in "Who's Who" or "American Men of Science"; Column 4: Number in "Who's Who" per 10,000 white population in 1890; Column 5: Number in "American Men of Science" per 10,000 white population in 1890; Column 6: Number in "Leaders in Education" per 100,000 white population in 1880 excluding any in "Who's Who" or "American Men of Science."

	1	2	3	4	5	6
Alabama	3.1	1.0	5.0	5.9	1.9	9.5
Arizona	4.0	2.3	7.4	4.6	3.6	8.6
Arkansas	2.4	1.1	5.2	3.2	1.6	7.1
California	6.4	4.6	6.2	7.2	5.0	7.0
Colorado	7.7	7.8	9.3	7.9	8.0	9.4
Connecticut	10.4	6.2	11.1	10.6	6.3	11.3
Delaware	7.4	2.9	8.2	9.1	3.5	10.0
Florida	3.2	1.2	3.3	6.1	2.0	6.3
Georgia	2.9	1.0	4.0	5.4	1.8	7.5
Idaho	12.9	7.1	12.3	14.5	7.7	13.8
Illinois	6.1	4.6	10.7	6.2	4.7	10.9
Indiana	5.2	5.2	13.5	5.3	5.3	13.8
Iowa	6.6	5.8	12.1	6.6	5.8	12.2
Kansas	5.1	4.9	15.2	5.3	5.0	15.9
Kentucky	3.5	1.7	5.7	4.1	2.0	6.8
Louisiana	2.1	1.1	3.2	4.4	2.2	6.6
Maine	7.0	5.3	17.0	7.0	5.3	17.0
Maryland	5.7	4.8	8.7	7.3	6.1	11.2
Massachusetts	11.2	6.8	13.0	11.4	6.8	13.2
Michigan	5.5	4.3	11.7	5.6	4.3	11.8
Minnesota	6.4	4.9	13.7	6.5	5.0	13.8
Mississippi	2.5	1.2	3.8	5.9	2.8	9.0
Missouri	4.8	3.2	10.1	5.1	3.3	10.8
Montana	10.2	6.7	15.3	11.4	7.5	17.1
Nebraska	6.6	4.1	19.7	6.6	4.1	19.8
Nevada	5.3	3.2	3.2	6.1	3.8	3.7
New Hampshire	7.6	5.6	13.3	7.6	5.6	13.3
New Jersey	6.1	3.1	5.0	6.3	3.2	5.1
New Mexico	2.0	1.9	2.5	2.2	2.1	2.8
New York	6.8	4.4	7.3	6.9	4.4	7.4
No. Carolina	3.7	1.7	5.4	5.9	2.5	8.7
No. Dakota	11.7	5.0	46.1	11.9	5.2	47.2
Ohio	6.5	4.8	12.5	6.7	5.0	12.8
Oklahoma	?	?	?	?	?	?
Oregon	6.7	5.0	10.3	7.2	5.3	11.0
Pennsylvania	5.3	3.6	8.6	5.4	3.7	8.8
Rhode Island	8.4	4.7	12.7	8.6	4.8	13.0
So. Carolina	3.5	1.8	5.9	8.8	4.4	15.1
So. Dakota	9.6	5.5	26.5	9.7	5.9	26.2
Tennessee	3.6	1.4	4.9	4.9	1.8	6.6
Texas	2.9	1.9	6.7	3.9	2.5	8.9
Utah	9.5	11.4	17.4	9.6	11.7	17.6
Vermont	7.6	5.9	12.9	7.7	5.9	13.0
Virginia	4.9	2.7	6.5	8.4	4.3	11.2
Washington	11.5	5.7	17.3	12.8	6.0	19.4
W. Virginia	4.2	2.5	9.4	4.4	2.6	9.8
Wisconsin	6.2	5.1	11.3	6.3	5.1	11.3
Wyoming	11.5	5.9	24.1	12.6	6.3	26.3

[3] What we should like to have as authoritative measures in place of the facts of Table I for any state is the percentage of those born in it in any period, say 1880, or 1880–1889, or 1870–1909, who would, before they died, or before they reached some specified age, be enrolled in Who's Who, American Men of Science, or any other list significant of superiority. But to obtain such facts for all years and states is impossible; and even to obtain them only for those states for which the number of births is known for those periods to which accessions to Who's Who and the American Men of Science can be assigned, for those persons who have reached age fifty, would require an enormous amount of labor.

1905, so that division by the sum of the 1890 and 1900 populations may give juster measures for the "American Men of Science" than division by the 1890 population alone.

TABLE II

AGE DISTRIBUTION OF SUPERIOR MEN

Year	Number born among a random thousand in: Who's Who, 1938–9	American Men of Science, 1938	Leaders in Education but not in Who's Who or A.M.S.
Before 1860	49	3	34
1860–1864	59	22	41
1865–1869	120	28	60
1870–1874	167	75	89
1875–1879	178	55	134
1880–1884	145	92	148
1885–1889	124	113	188
1890–1894	87	148	183
1895–1899	56	153	91
1900–1904	12	166	30
1905–1909	3	124	1
1910 or later	..	21	1

The facts for each state by these measures appear in Table III. They still are imperfect as measures of the comparative productivity of superior persons in the forty-eight states, but the errors will be small in comparison with the differences shown, and the effect of the errors upon the correlations we shall later present will be mainly to act as a factor of safety, reducing them all slightly.

TABLE III

SUPERIOR BIRTH RATES AND RANKS FOR EACH STATE

Column 1: Number in "Who's Who" (1938) per million in the sum of the 1870, 1880 and 1890 populations; Column 2: Number in "American Men of Science" (1938) per million in the sum of the 1890 and 1900 populations; Column 3: Number in "Leaders in Education" (1932) (but not in "Who's Who" or "American Men of Science") per million in the sum of 1870, 1880 and 1890 populations.

	1	Rank*	2	Rank*	3	Rank*
Ala.	103	41	47	47	17	39, 40
Ariz.	116	40	95	36	22	34
Ark.	79	46	52	44	17	39, 40
Calif.	211	16	206	22	20	36
Colo.	232	11	340	2	28	28, 29
Conn.	339	2	278	5	36	17, 18
Del.	248	9	139	31	27	30
Fla.	102	42	49	45, 46	11	46, 47
Ga.	97	44	44	48	13	43–45
Idaho	309	3	252	10	29	25–27
Ill.	200	20	203	24	35	19
Ind.	177	30	242	12	46	8
Iowa	226	12	267	7	42	11–15
Kan.	182	29	240	13	54	5–7
Ky.	118	39	79	40	19	37
La.	71	47	49	45, 46	11	46, 47
Maine	234	10	256	8, 9	57	2–4
Md.	193	24	226	18	29	25–27
Mass.	366	1	301	3	42	11–15
Mich.	183	27, 28	198	25	39	16
Minn.	199	21	210	21	42	11–15
Miss.	86	45	53	43	13	43–45
Mo.	157	33	146	30	33	20
Mont.	197	22, 23	249	11	30	24
Nebr.	183	27, 28	204	23	54	5–7
Nev.	217	15	167	28	13	43–45
N. H.	253	8	269	6	44	9
N. J.	197	22, 23	135	32	16	41, 42
N. M.	65	48	84	37	8	48
N. Y.	224	13	197	26	24	31
N. C.	126	35	76	41	18	38
N. D.	187	26	186	27	74	1
Ohio	219	14	227	16, 17	42	11–15
Okla.	120**	38	107	35	31**	22, 23
Ore.	201	19	218	19	31	22, 23
Pa.	173	31	163	29	28	28, 29
R. I.	278	5	211	20	42	11–15
S. C.	121	37	82	38	21	35
S. D.	205	17	256	8, 9	57	2–4
Tenn.	121	36	63	42	16	41, 42
Texas	101	43	81	39	23	32, 33
Utah	308	4	492	1	57	2–4
Vt.	255	7	288	4	43	10
Va.	169	32	125	33	23	32, 33
Wash.	189	25	233	15	29	25–27
W. Va.	144	34	111	34	32	21
Wis.	202	18	227	16, 17	36	17, 18
Wyo.	261	6	239	14	54	5–7

* If two states have the same birth-rate of superior men, the ranks of both are given for each. For example, Michigan and Nebraska, with a rate of 183 for "Who's Who" persons are ranked 27, 28. Similarly, if three or more states have the same rank.

** Estimated.

As a second, and in some respects better, method of computing state birth-rates of Who's Who persons, I have computed the facts of Table IVA, in which the number of persons reported in two thousand pages of "Who's Who" for 1838–1839 and born in 1856 through 1864 is divided by the total number of births in the state in question in 1860, and similarly for "Who's Who" persons born in 1866 through 1872 and the total births in 1870, "Who's Who" persons born in 1876 through 1884 and the total births in 1880, etc.

TABLE IVA

THE BIRTHS OF "WHO'S WHO" PERSONS IN EACH STATE (EDITION OF 1838) DURING CERTAIN PERIODS IN RELATION TO THE TOTAL NUMBER OF BIRTHS IN THE STATE AT APPROXIMATELY THE SAME PERIOD

	W (56–65) / B 1860	W (66–75) / B 1870	W (76–85) / B 1880	W (86–95) / B 1890	Rank
Maine	411	797	670	451	13
N. Hampshire	538	1289	738	361	7
Vermont	587	898	680	276	11
Massachusetts	653	1437	1041	513	2
Rhode Island	524	894	809	517	8
Connecticut	754	1150	998	504	4
New York	308	683	576	359	19
New Jersey	300	623	434	275	27, 28
Pennsylvania	254	520	394	228	32
Ohio	306	644	513	318	23
Indiana	231	417	399	278	33
Illinois	278	552	454	246	30
Michigan	251	668	458	266	27, 28
Wisconsin	377	532	425	259	29
Minnesota	442	682	473	257	20
Iowa	270	618	586	310	22
Missouri	174	402	324	246	34
No. Dakota	0	613	576	282	24, 25
So. Dakota	0	1538	901	335	5
Nebraska	497	891	425	291	16
Kansas	333	696	325	341	24, 25
Delaware	271	929	570	262	17
Maryland	264	516	452	271	31
Virginia	167	486	332	218	35
W. Virginia	170	411	285	159	36
No. Carolina	101	377	233	192	37
So. Carolina	136	372	208	154	38
Georgia	99	271	167	126	44
Florida	119	223	213	190	41
Kentucky	137	312	240	133	39
Tennessee	91	337	207	166	40
Alabama	94	300	189	126	42
Mississippi	100	211	173	98	44
Arkansas	98	252	117	89	47
Louisiana	78	222	134	82	48
Oklahoma	?	?	?	?	26*
Texas	95	287	173	134	43
Montana	?	637	1131	365	12
Idaho	?	1810	968	524	3
Wyoming	?	641	1064	681	10
Colorado	0	1035	1282	367	6
New Mexico	0	114	50	134	45
Arizona	?	0	770	269	18
Utah	297	878	630	339	15
Nevada	2941	1411	578	401	1
Washington	302	1464	717	328	9
Oregon	248	722	516	383	21
California	403	852	644	418	14

* Estimated.

W (56–65) = 100,000 × the number of persons on 2000 pages of Who's Who born in the state in 1856 to 1865 inclusive.

W (66–75) = 100,000 × the number of persons on 2000 pages of Who's Who born in the state in 1866 to 1875 inclusive.

W (76–85) = 100,000 × the number of persons on 2000 pages of Who's Who born in the state in 1876 to 1885 inclusive.

W (86–95) = 100,000 × the number of persons on 2000 pages of Who's Who born in the state in 1886 to 1895 inclusive.

B 60 = the number of births in the state in 1860
B 70 = the number of births in the state in 1870
B 80 = the number of births in the state in 1880
B 90 = the number of births in the state in 1890

Table IVB reports the same facts but expressed in each case as a deviation from the median of the column's measures. The measures for 56 to 65, 76 to 85, and 86 to 95 are multiplied by factors to give them general equality with the 66 to 75 measures and thus show more clearly the degree of consistency of the rates for the same state at different periods.

The correlation of the sum of the rates of Table IVA with the "Who's Who" rates in Table III is .88. The correlation for a weighted sum in which each period

is given approximately equal weight is .90.

I have used this method for the persons listed on a thousand pages of the 1938 edition of "American Men of Science."[4] The correlations corresponding to the .88 and .90 for "Who's Who" persons are .92 and .90. It seemed unnecessary to undertake these very laborious computations for the "Leaders in Education."

As a general measure of a State's relative productivity of superior persons we may use a composite (called SBQ) of the three per-populations measures of Table III and the two per-births measures. (I use the averages, but medians would do as well.) Any reasonable weighting of the five will do; I give approximately equal weight to each of the five, which means that "Who's Who" measures and "American Men of Science measures each have about twice the weight of the "Leaders in Education" measures. The values of SBQ for each state appear in Table V. The numbers are reduced to values such that the median state is 100, but their relative proportions are approximately the same as would be found in the per population rates or in the per births rates. For example, the state with the highest SBQ (170) *does* produce at a rate about five times that of the state with the lowest SBQ (32). These composite rates or SBQ's for the production of superior persons are still not perfect, but would probably correlate well over .90 with the ratings that would be found if the achievements of every person born from 1855 to 1900 were examined and evaluated by a competent jury of experts and if those put in the top one or two per cent. were classified by state and year of birth and the resulting numbers were compared with the total numbers of births in each state in each year.

[4] Tables like IVA and IVB were prepared but are omitted here for lack of space.

TABLE IVB

THE FACTS OF TABLE IVA, EACH BEING DIVIDED BY 10, EXPRESSED AS A DEVIATION FROM THE MEDIAN OF ITS COLUMN, AND MULTIPLIED BY A FACTOR (1.65) FOR THE 1860 COLUMN, 1.00 FOR THE 1870 COLUMN, 1.26 FOR THE 1880 COLUMN, AND 3.0 FOR THE 1890 COLUMN) TO MAKE THE VARIABILITY EQUAL FOR EACH COLUMN, AND PERMIT EASY COMPARISONS OF THE BIRTH-RATES OF THE SAME STATE IN THE FOUR PERIODS

	W(56–65) / B 1860	W(66–75) / B 1870	W(76–85) / B 1880	W(86–95) / B 1890
Maine	23	16	26	54
New Hampshire	43	65	34	27
Vermont	53	26	28	0
Massachusetts	63	80	78	72
Rhode Island	58	26	43	72
Connecticut	79	52	67	69
New York	5	5	14	24
New Jersey	5	−1	−4	0
Pennsylvania	−3	−11	−9	−15
Ohio	5	1	6	12
Indiana	−7	−21	−9	0
Illinois	0	−8	−1	−9
Michigan	−3	3	−1	−3
Wisconsin	16	−10	−5	−6
Minnesota	28	5	1	6
Iowa	0	−2	15	12
Missouri	−16	−23	−18	−9
North Dakota	−8*	−2	14	3
South Dakota	−8*	90	55	18
Nebraska	36	26	−5	6
Kansas	10	6	−18	21
Delaware	0	29	14	−3
Maryland	−2	−12	−1	0
Virginia	−18	−15	−16	−18
West Virginia	−16	−22	−23	−36
North Carolina	−28	−26	−26	−24
South Carolina	−23	−26	−33	−36
Georgia	−30	−36	−38	−45
Florida	−26	−41	−32	−24
Kentucky	−23	−32	−28	−42
Tennessee	−30	−30	−33	−33
Alabama	−30	−33	−35	−45
Mississippi	−28	−42	−37	−54
Arkansas	−30	−38	−44	−57
Louisiana	−33	−41	−42	−57
Oklahoma	?	?	?	?
Texas	−30	−35	−36	−42
Montana	?	0	84	27

Idaho	?	118	63	75
Wyoming	?	1	75	123
Colorado	?	40	104	27
New Mexico	?	−52	−51	−42
Arizona	?	?	39	−3
Utah	3	24	21	18
Nevada	440	78	14	39
Washington	5	83	32	15
Oregon	−5	9	6	33
California	21	22	23	42

* Estimated.

I have sought in vain for data on birthplace for any large groups of musicians, artists, highly-skilled craftsmen, engineers, clergymen or the like to extend Table III and Table V. I have also sought in vain for data on the birthplaces of criminals, feeble-minded, psychopaths and other defectives, delinquents and dependents to make a table to contrast with Table III and Table V. It is probable, but not at all certain, that the states have differed in the production of superior artists, technicians, farmers, etc., in the same ways that they have differed in the production of superior workers in science and education. It is probable, indeed almost certain, that a state which produced relatively many high on a scale for human quality produced relatively few that were low in such a scale.

TABLE V

SUPERIOR BIRTH-RATE OR QUOTIENT, SBQ, AND RANK FOR EACH STATE

State	Rate SBQ	Rank	State	Rate SBQ	Rank
Ala.	41	42	Neb.	115	16
Ariz.	72	33	Nev.	113	18
Ark.	37	44	N. H.	140	6
Cal.	103	22	N. J.	77	32
Colo.	141	5	N. M.	35	47
Conn.	148	3	N. Y.	98	26
Del.	93	29	N. C.	51	38
Fla.	38	43	N. D.	118	12
Ga.	36	46	Ohio	110	19
Ida.	142	4	Okla.	71	34
Ill.	97	27	Ore.	102	24
Ind.	104	21	Pa.	83	30
Iowa	116	13	R. I.	128	11
Kan.	115	14	S. C.	51	37
Ky.	50	39	S. D.	139	7
La.	32	48	Tenn.	46	41
Me.	130	10	Tex.	49	40
Md.	95	28	Utah	170	1
Mass.	164	2	Vt.	132	9
Mich.	99	25	Va.	70	35
Minn.	108	20	Wash.	115	15
Miss.	36	45	W. Va.	67	36
Mo.	78	31	Wis.	102	23
Mont.	114	17	Wyo.	136	8

It is then worth while to examine the affiliations (*i.e.*, the correlations or covariances) of high per-capita production of the sort measured by SBQ. For the year 1930 or near it, I have, for each state, six instructive measures;

G, an index of the general goodness of life for good people, based on 37 measures.

I, an index of the per capita income of the residents, based on 9 measures.

P, an index of certain personal qualities of the residents, based on 10 measures.

G_{wh}, an approximate index of the goodness of life for good white people, based on 9 measures.

I_{wh}, an approximate index of the per capita income of white residents, based on 3 measures.

P_{wh}, an approximate index of the personal qualities of white residents based on 5 measures.

The constituent measures and their weights are described in Note 2 at the end of this article.

We would prefer to study measures of the condition of each state in 1870, 1880, 1890, and 1900 rather than these measures of its condition in 1930, but only a very few are available for these earlier years. For 1900, I have measures of certain significant facts, namely the percentage of native whites aged ten or over that were illiterate, the percentage of farms that were owned by those living on them, the percentage of non-farm

homes owned by those living in them, and an index, G P of 1900, described in Note 3 at the end of this article.

The correlations, given in Table VI, show very close bonds between SBQ and the quality of the population in 1930. Whatever causes the former accounts for three fourths of the variation in the latter ($.87^2$). No combination of the measures in a multiple correlation will add anything considerable to this. In particular, income adds almost nothing.

The combined force of P_{wh} and per cent of colored reversed accounts for 68 per cent. of the variation in SBQ, the allotment of the 68 per cent. being as follows:

.27 per cent. is due to what is measured by P_{wh} and not by per cent. colored reversed.

.13 per cent. is due to what is measured by per cent. colored reversed and not by P_{wh}.

.28 per cent. is due to something that is common to P_{wh} and per cent. colored reversed.

The relation between the 1930 P and the births a half-century before is due in only small measure to the influence of the superior persons in question upon the residents of the state in which they were born. For only a small minority of them stay there. The medians are 34% for "Who's Who" persons and 19% for "American Men of Science." And those that emigrate do not go especially to states which are high in P in 1930. On the contrary they favor states low in P.[5] Doubtless superior men benefit the state where they live, but the important fact is that the kind of state which gives birth to many of them probably was high in P in 1880.

It certainly was in 1900. The correlation of the three birthrates with even so partial a symptom of P as native white literacy is .77. The correlation with the percentage of farmers owning their farms is .63. The correlation with ownership of non-farm homes is .37. There can be little doubt that if the ten items

TABLE VI

CORRELATIONS OF A COMPOSITE SUPERIOR-BIRTH RATE, SBQ, FOR THE 48 STATES IN 1930

With G of 1930	.79
" P " "	.87
" I " "	.48
" G_{wh} " "	.72
" P_{wh} " "	.80
" I_{wh} " "	.06
With percentage of colored (reversed) in 1930	.77
With G P of 1900	.81
With native white literacy of 1900	.77
With percentage of farmers owning their farms in 1900	.63
With percentage of non-farm population owning their homes in 1900	.37

of the P score were available for 1900, the correlation of SBQ with P of 1900 would be over .80. If these items were available for the white population of 1900 the correlation with a P for whites alone in 1900 would also almost certainly be over .70. I know of no facts which would cause the correlations to be lower in 1870 or 1880, and there are some facts which would cause them to be higher.

We may conclude therefore that the production of superior men is surely not an accident, that it has only a slight affiliation with income, that it is closely related to the kind of persons residing in New England and in the block formed by Colorado, Idaho, North Dakota, South Dakota, Utah and Wyoming, from 1870 to 1900, and that these persons probably diverged from the average of the country toward the qualities which make persons in 1930 learn to read, graduate from high school, spend public funds on libraries rather than roads and sewers, own their homes, avoid homicide, be free from syphilis, etc., as measured by the Index P.

[5] This will be substantiated in a later article on the interstate migration of superior men.

APPENDIX

NOTE 1—COMPARABLE INVESTIGATIONS

Geisert has computed the ratio of the percentage of "Who's Who" persons born in Virginia in 1850–1860 to the percentage of white women 20 to 44 years of age in Virginia at that period, and similarly for each of the ten other states of the Southeast. (Geisert, H. L., "The Trend of the Interregional Migration of Talent: The Southeast, 1899–1936." 1939. *Social Forces*, 18: 41–47.) He has done this also for the period 1884 to 1886. (For this period, native-born white women were used.) The Southeastern states were in general below the ratio (1.00) for the United States as a whole. Their ratios as estimated from Geisert's chart were as shown below:

	1850–1860	1884–1886
Alabama	.52	.68
Arkansas	.25	.41
Florida	1.00	.76
Georgia	.59	.74
Kentucky	.62	.67
Louisiana	.58	.60
Missisippi	.58	.83
North Carolina	.52	.81
South Carolina	1.04	1.26
Tennessee	.44	.69
Virginia	.76	1.17

His figures for the '84–'86 group correlate .91½, and the averages of his figures for the two periods correlate .90½, with our figures for the number divided by the white population in 1880.

Vance has recently reported the "average birth rate" of native-born whites included in the "Dictionary of American Biography" and born from 1790 to 1860, reckoned on the native-born white population. (Vance, R. P., "The Geography of Distribution: The Nation and Its Regions 1790–1927." 1939. *Social Forces*, 18: 168–179.) The District of Columbia was highest with a rate of 31.4 per million. Massachusetts, Connecticut and Rhode Island had above 16.0. Maine, New Hampshire, Vermont, New York and South Carolina had from 12.0 to 15.9. New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia and Georgia had from 8.0 to 11.9. Ohio, Michigan, Wisconsin, Kentucky, Tennessee, North Carolina, Alabama, Mississippi and Louisiana had from 4.0 to 7.9. The other states had less than 4.0. If native-born Negroes had been included these rates would, of course, have been very different, but the general magnitude of the variation would probably have been increased.

In those early years the ranking of the eastern states in the production of superior men was much like what it is now (the correlation for the 24 listed above being .73 or .76 between Vance and Thorndike ranks according as the Thorndike ranks are on a basis of total population or white population). The western states and territories were then all very low, and about equally low by Vance, but possibly the populations he used as bases for them were too large, or especially lacking in women.

NOTE 2.—CONSTITUENTS OF THE G SCORE

Item*	ITEMS OF HEALTH	Approximate weight for states
131	Infant death-rate reversed	13
132	General death-rate reversed	9
134	Typhoid death-rate reversed	5½
136	Appendicitis death-rate reversed	3½
137	Puerperal diseases death-rate reversed	5½
	ITEMS OF EDUCATION	
53	Per capita public expenditures for schools	8
54	Per capita public expenditures for teachers' salaries	7
55	Per capita public expenditures for textbooks and supplies	8
56	Per capita public expenditures for libraries and museums	6
21	Percentage of persons sixteen to seventeen attending schools	4½
22	Percentage of persons eighteen to twenty attending schools	7½
23	Average salary, high-school teachers, elementary-school teachers, and supervisors	7½
	ITEMS OF RECREATION	
57	Per capita public expenditures for recreation	7½
17	Per capita acreage of public parks	2
	ECONOMIC AND "SOCIAL" ITEMS	
107	Rarity of extreme poverty	6½
108	Rarity of less extreme poverty	6½
153	Infrequency of gainful employment for boys 10–14	4½

154 Infrequency of gainful employment for girls 10–14	5½
223 Average wage of workers in factories	4
106 Frequency of home ownership (per capita number of homes owned)	6
248 Per capita support of the Y. M. C. A.	6
201 Excess of physicians, nurses, and teachers over male domestic servants	6
98 Per capita domestic installations of electricity	5½
99 Per capita domestic installations of gas	7
102 Per capita number of automobiles	5
103 Per capita domestic installations of telephones	10
104 Per capita domestic installations of radios	6½

OTHER ITEMS

31 Percentage of literacy in the total population	4
25 Per capita circulation of Better Homes and Gardens, Good Housekeeping and the National Geographic Magazine	6
26 Per capita circulation of the Literary Digest	5½
133 Death rate from syphilis (reversed)	4
241 Death rate from homicide (reversed)	3½
243 Death rate from automobile accidents (reversed)	3½
12 Per capita value of asylums, schools, libraries, museums, and parks owned by the public	6
16 Ratio of value of schools, etc., to value of jails, etc.	3
11 Per capita public property minus public debt	5

* The items are more fully described on pages 173 to 187 of "Your City" by E. L. Thorndike, and also in *Ann. N. Y. Acad. Sci.*, 39: 214–223.

After the 37 scores were multiplied by amounts such as to make their standard deviations be proportional to the numbers listed above as approximate weights, the sum for each state (called G3) was combined with a score (G1) which was computed by subtracting the number of features among the 37 in which that state was below the median of the 48 states from the number in which it was above the median of the 48. G3 and G1 had relative weights of approximately 2 and 1 respectively in the final G score.

It should be kept in mind that Items 11, 12, 16, 56, and 57 are for a state's own property, debt, and expenditures, not for these plus those of the smaller governmental units within its boundaries.

CONSTITUENTS OF THE I SCORE

	Approximate weight for states
Income tax returns (over $2,500)	15
Income tax returns (over $5,000)	7
Average wages: teachers and supervisors	3½
Average wages: retail store employees	7
Average wages: factory employees	7
Expenditures: rent (or equivalent)	3½
Expenditures: food-store sales	4½
Expenditures: cigar-store sales	1
Expenditures: drug-store sales	1

This list has one notable weakness, in that the expenditures are such as respectable people make for respectable purposes. The expenditures for prostitutes, gambling, forbidden drugs, intoxicants, and more or less disreputable entertainment in these cities could not be estimated. This weakness acts as a factor of safety in the case of some of our most important conclusions.

CONSTITUENTS OF THE P SCORE

The personal qualities index, P, is a weighted composite of the deviations from the median in the items listed below, the weights being approximately as stated.

Item	Approximate weight for states
30 Per capita number of graduates from public high schools in 1934	5
261 Percentage which public expenditures for the maintenance of libraries was of the total	2
31 Percentage of illiteracy (reversed)	2⅜

33	Percentage of illiteracy among those aged 15–24 (reversed)	$2\frac{1}{8}$
106	Per capita number of homes owned	5
201	Per capita number of physicians, nurses and teachers minus male domestic servants	4
103	Per capita number of telephones	$2\frac{1}{8}$
207d	Number of male dentists divided by number of male lawyers	2
133	Per capita number of deaths from syphilis (reversed)	$2\frac{3}{8}$
241	Per capita number of deaths from homocide (reversed)	$2\frac{1}{8}$

Constituents of G_{wh}: Items 131, 134, 137, 21, 22, 153, 154, 104, and 243 from the G list above, but in each case for the white population of the state. The weights were approximately as in the G composite.

Constituents of P_{wh}: Items 31, 106, 133 and 241 from the P list above, but computed for the white population, and also the percentage of white farmers owning their farms.

NOTE 3

G P of 1900 is a composite score including:
(1) the percentage of residents 5 to 18 years old enrolled in public schools.
(2) the number of days public schools were in session.
(3) the expenditures per pupil in actual attendance for teachers and supervisors.
(4) the expenditures per pupil in actual attendance for all other items, excluding outlays for buildings and interest on bonds.
(5) the percentage of literacy for the white population aged 10 or over.
(6) the percentage of farmers owning their farms.
(7) the percentage of non-farm families owning their homes.
(8) the percentage which the white population was of the total population.

CRITERIA OF THE EMPIRICAL METHOD

By Dr. PAUL CRISSMAN
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IN its widest sense, the meaning of "empirical" propositions may best be understood when contrasted with that of "formal" ones. Formal propositions consist of the analytic statements established by logic and mathematics; empicical propositions (hypotheses) consist of the synthetic statements verified by reference to existential objects and events. Formal propositions derive their validity from conventions, and, from the point of view of empricism, are materially empty and constitute a system of tautologies. Formal propositions concern themselves solely with the structure of verbal systems and the conventions whereby terms and propositions of one language may be translated into terms and propositions of another and different language, and are, in any empirical sense, wholly devoid of "truth" value. In other words, terms and propositions refer to or designate (1) other terms and propositions, and (2) perceptual objects and events, or identities discernible in or among such objects and events. In sum, if a hypothesis be empirical, it must designate some property or invariant relation exemplified in some class or domain of things or events, or else imply other propositions that terminate in such reference.

Now empirical science, our scientists and scientific text-books tell us, is concerned with "facts." So it is, the tested hypotheses that constitute scientific knowledge are suggested by facts and are in turn verified by reference to them. But what are facts?

The word "fact" embraces at least three types of referents. (1) "Fact" sometimes denotes objects and events discriminable in sense perception, together with relations perceived between them.

"The end of this pointer coincides with that mark on the scale," "This band of color lies between those two bands," are facts in this sense. Facts in this sense are distinct from the hypotheses we make about them; indeed, such facts are instituted or sought out by us in order to test the hypotheses we formulate. (2) "Fact" sometimes denotes propositions or judgments which *interpret* the data discriminated in sense perception. "This object is ferrous," "That object is a protozoan," are facts in this sense. All inquiry must take for granted a host of facts of this kind, although we may later reject some of them as false. (3) "Fact" also denotes propositions which truly assert some "invariant relation" or "constant conjunction of characters" between or among a plurality of things and events. "All planets revolve about the sun at velocities such that their radii from the sun describe equal areas in equal times," "Any nerve fiber must either respond with its whole capacity for response or none at all," are facts in this sense. A hypothesis is made "true," is "verified" and thereby becomes a fact when, as an experimental operation, it leads to the institution or discovery of facts in the first sense.

Consequently, facts are not determinate entities existing in nature that command attention in virtue of characteristics intrinsic to them; they are not, like berries on a bush, just waiting there for any one to pluck who runs. Facts, in so far as they are significant for scientific inquiry, are instituted or sought out by us for the purpose of testing a hypothesis. They are relative to the purposes of the inquirer on the one hand, and to the body of antecedently verified knowledge relevant to the particular inquiry on the other hand. Scientific inquiry is purposive; it is no mere idle staring at some inchoate flux of sensory elements passing in review before awareness. Some hypothesis, however arrived at, guides and directs all significant inquiry; otherwise we should never look for or seek to institute any facts. To paraphrase the famous dictum of Kant, hypotheses without perceptual facts are devoid of empirical meaning, perceptual facts uninformed by hypotheses are blind or uncognized.

Thus both concepts (hypotheses) and percepts (existential data) are essential to empirical science. The relation between them is reciprocal; the hypothesis embodies that which is *known* of the percepts, the percept constitutes the objective or public data of which knowledge is had. Moreover, there is another sense in which the distinction between hypothesis and perceptual fact is relative, when by a hypothesis is meant a proposition which *may* be true, but for which the perceptual evidence in verification of it is never complete. Since it it impossible to demonstrate the nonexistence of negative instances, we can never attain complete proof for any hypothesis the number of whose existential referents is indeterminate. Moreover, this denotative indeterminateness is characteristic of all scientific hypotheses. Hence the commonplace that scientific laws are at best only more or less probable. Suppose, *e.g.*, we assert that the volume of a gas varies inversely as the pressure exerted upon it, or that two or more bodies revolving about the sun move at velocities such that their radii describe equal areas in equal times. Assume that, within certain limits, a gas under terrestrial conditions will always vary in volume approximately as described; assume that, within the limits of the conditions set by the solar system, planetary motions will always conform to Kepler's laws; yet, for aught we know, there *may* exist elsewhere in the universe domains wherein a gas will not behave as described and where Kepler's laws of planetary motion will not hold true.

In terms of the meaning of "empirical" distinguished above on the one hand, and of the interdependence between hypotheses and perceptual facts on the other, let us consider a supposed instance of verification of a hypothesis. Take, for example, the hypothesis that H_2O, under pressure of one atmosphere, will always boil at 100 degrees Centigrade. Suppose we satisfy the conditions required by the hypothesis and then find that in the experiment the H_2O is actually observed to boil at the temperature prescribed. This "crucial" experiment is then supposed to "verify" the hypothesis. Yet, even assuming no error in measurement, this experiment *proves* only that the particular H_2O employed in the experiment was observed to boil at the instant when the measuring rod was observed to register 100 degrees Centigrade. By what logic, then, do we infer therefrom that when the same conditions are fulfilled the same temporal coincidence between boiling and a certain temperature reading will always be observed? The answer is, by no *valid* logic, for if we make such an inference, we commit the obvious fallacy of reasoning from one to all. Indeed, it is highly doubtful that, on the basis of a single observation of the temporal conjunction of two such characters, it would ever occur to us that the two characters were related in any way other than by chance.

Suppose, however, we repeat the experiment a number of times and observe the same results each time. Does not *this*, then, prove the hypothesis? Unhappily, it does so no more than the single experiment. For the number of such possible experiments is indeterminate if not indeed infinite; one "crucial" experiment proves precisely as much or as little as does any number of repetitions of it. For, if we ascribe to all possible instances of a phenomenon some property or relation observed to hold only of a number of selected instances of it, we commit the simple fallacy of reasoning from some to all. But to reason from some to all is neither more nor less fallacious than to reason from one to all; indeed, there are no degrees of fallaciousness. In truth, the ascription of necessity to the coincidence between boiling and a given temperature reading observed in a number of instances is but the verbalization of that inexpungable habit of mind whereby we *come to expect* the same results each time the experiment is repeated. Expectation, however, is a psychological attitude; it is not demonstration of proof, for this latter is a logical process. Expectations do of course come true, and, for practical purposes, the obtainment of the same results by repetitions of the same experiment does in fact sooner or later succeed in banishing doubt, but this again is a psychological, not a logical, process. It is in dissipation of doubt, whether by one or by many experiments, that verification at least in part consists.

But verification is more than the dispelment of doubt; it is, in its more positive phase, the establishment of well-grounded belief. However, all depends upon the manner in which belief is established. In the words of a recent writer,[1] the belief in the truth of a hypothesis is established "in a simultaneous experience of the concepts and the given. The process of verification consists in the observation of instances of the characters expressed in a proposition. One may say that propositions correspond to, or agree with, experience. This relation of a true proposition to experience is fundamental and can be explained only in terms of synonyms; the fundamental fact is that we can determine the correspondence to experience of propositions about experience." Thereby alone is belief established or a hypothesis verified. But this again is a psychological, not a logical, process.

[1] V. F. Lenzen, "Physical Theory," p. 272.

Moreover, it is commonly supposed by scientists that a single crucial experiment may often decide between two rival theories.[2] For if one theory implies a verifiable proposition which contradicts a proposition implied by a second theory, by performing the experiment, it is believed, we can then eliminate one of them.

Consider two hypotheses: H_1, the hypothesis that light consists of very small particles traveling at great speeds, and H_2, the hypothesis that light is a form of wave motion. Both hypotheses explain a class of events E, *e.g.*, the rectilinear propagation of light, the refraction of light, the reflection of light. But H_1 implies the proposition p_1 that the velocity of light in water is *greater* than in air; while H_2 implies the proposition p_2 that the velocity of light in water is *less* than in air. Now p_1 and p_2 can not both be true. Here, it would seem, is an ideal case for performing a *crucial* experiment. If p_2 should be confirmed by experiment, p_1 would be refuted, and we could validly conclude that the hypothesis p_1 is false. Yet nearly a century ago Foucault showed that light travels faster in air than in water. Accordingly, the corpuscular theory of light should have been discarded once and for all.

Yet recent physics has revived Newton's corpuscular hypothesis in order to account for certain optical effects. Must we not then qualify this doctrine of crucial experiments?

The answer is simple, but calls attention once more to the interdependence between theory and observation. In order to deduce the proposition p_1 from H_1, and in order to perform the experiment of Foucault, many other assumptions, K, must be made about the nature of light and the instruments we employ in measuring its velocity. As a result, it is not only the hypothesis H_1 that is tested by the experiment, it is H_1 and K. The logic of the crucial experiment therefore is as follows: If H_1 and K, then p_1; but p_1 is false; therefore either H_1 is false or K (in part or in whole) is false. Now if we have adequate grounds for believing that K is not false, H_1 is refuted by the experiment. Nevertheless, the experiment tests *both* H_1 and K. If, in the interest of consistency, it is found necessary to revise some one or another of the assumptions contained in K, the crucial experiment must be reinterpreted, and it need not then decide against H_1.

Every experiment, therefore, tests not *only* an isolated hypothesis, but *also* the whole body of relevant knowledge logically involved in it. If the experiment is claimed to refute an isolated hypothesis, this is because the other assumptions relevant to it are believed to be well founded. But this latter belief may later turn out to be questionable or even mistaken.

This point is important enough to deserve reinforcement by another illustration. Suppose we wish to discover whether physical space is Euclidean, *i.e.*, whether the sum of the angles of a physical triangle is equal to two right angles. We select as vertices of such a triangle three stars, and as its sides the paths of light rays traveling from vertex to vertex. By making a series of measurements we can obtain the magnitude of each of the angles of this triangle. Suppose the sum of their several magnitudes is *less* than two right angles. Must we then conclude that Euclidean geometry is not truly descriptive of physical space? Not at all. At least three alternative explanations are open to us: (a) we may account for the difference between the theoretical and observed values in terms

[2] This point, as well as the two illustrations cited in implementation of it, we borrow from Cohen and Nagel's "An Introduction to Logic and Scientific Method," pp. 219–221. Moreover, much of the language of this section of our paper, as well as a number of illustrations appearing elsewhere in it, are from the same source.

of errors in measurement; (b) we may conclude that physical space is non-Euclidean; or, (c) we may conclude that the lines joining the vertices of the triangle are not straight lines, *i.e.*, we may conclude that Euclidean geometry is physically true, but that light does not travel in Euclidean straight lines in interstellar space. If we accept the first alternative then, as descriptive of physical space, Euclidean geometry may be either true or false; if we accept the second alternative, we do so on the assumption that light travels rectilinearly, an assumption which, although supported by much evidence, is not indubitable; if we accept the third alternative, it may be because we have evidence for denying the rectilinear propagation of light, or else because greater consistency is maintained in the body of our physical knowledge as a consequence of this denial.

"Crucial experiments," we again conclude, are crucial against a hypothesis only in case we possess a set of assumptions which we are unwilling to surrender. But no guarantee can be given that some portion of such assumptions will not later be abandoned.

In order that a hypothesis qualify as empirically true or verified, it must satisfy the following criteria: (1) it must be *testable;* (2) it must be *consistent;* and, (3) it should be as *simple* as possible.

(1) The hypothesis must be testable: *i.e.*, it must prescribe some definite mode of operation, either of observation or of experiment, whereby its "truth" value can be tested. In operational terms, the hypothesis must be statable in such form as to prescribe specific operations which institute the phenomena (facts in the first sense) requisite to satisfy it. Because it can not be translated into a definite experimental operation, the hypothesis that "God is the First Cause of all events in nature" is untestable and hence is empirically meaningless. In contrast, Kepler's laws of planetary motion *are* verifiable, because they lead to the discovery of events that satisfy them.

Put otherwise, a hypothesis must be formulated in such a manner that deductions can be made from it, and that a decision can be reached as to whether or no it explains the facts considered. This decision may be reached either directly or indirectly. It is reached *directly* when the hypothesis is testable without the mediation of other hypotheses deducible from or related to it, or when the hypothesis itself prescribes operations that institute the data that satisfy it. The hypothesis that "H_2O, under pressure of one atmosphere, will boil at 100 degrees Centigrade," or that, "Within certain limits, and under certain specifiable conditions, the volume of a gas will vary inversely as the pressure exerted upon it," are verifiable in this direct manner. However, many hypotheses, especially the more general and fundamental of scientific laws, are verifiable only *indirectly.* The hypothesis must then be restated in such a manner that there are inferable from it other propositions which, supplemented by certain mathematical and logical operations, institute data that verify the derived hypotheses. Thus the hypothesis that "The sun and the planet Mars attract each other proportionately to their masses and inversely as the square of their distances from each other" can not be confirmed directly by observation. But one set of consequences from this hypothesis, that the orbit of Mars is an ellipse with the sun as its focus, and that, therefore, given certain initial conditions, Mars should be observable at different points on the ellipse at certain times, is capable of being verified.

In any case, whether directly or indirectly, the hypothesis must suggest a definite operation of observation or of experiment, otherwise it is impossible to test and verify it. The hypothesis that

the universe is contracting in such a manner that all linear measures shrink in the same ratio is empirically meaningless if it can lead to no operation from which observable consequences follow.

(2) The hypothesis must also be *consistent*. For, as we have seen, a given experiment tests not only the particular hypothesis in question but also the body of hypotheses relevant to it. No hypothesis acquires cognitive status for science if the acceptance of it necessitates the surrender of other hypotheses already accepted as scientifically well grounded. Thus the hypothesis that "God created the world during a six-day period some thousands of years ago" is inconsistent with a large number of hypotheses now accepted as commonplace truths in natural science. Thus the hypothesis that "Light waves or corpuscles are unaffected by gravitation" is inconsistent with differences recently discovered in measurements of the apparent position of a star when seen near the visible edge of the sun as compared to its position to the same neighboring stars when far removed from the sun.

Consistency, while a logical relation, in no way implies logical deducibility. Two or more hypotheses are *consistent* with each other when their respective meanings are such that *no one of them implies the negation of any other of them.* Thus the hypothesis that "The helium atom consists of one proton and two electrons," and the hypothesis that "Pleasure is the sole and constant object of human desire," are consistent with each other. Indeed, two or more hypotheses may be consistent with, yet logically independent of, each other. For two hypotheses are independent of each other when they are such that the truth or falsity of either implies nothing as regards the truth or falsity of the other.

Furthermore, a hypothesis must be consistent not only with the body of accepted hypotheses, it must also be consistent with *all* the data (facts in the first sense) relevant to it. Precisely what data are relevant to a given hypothesis must be determined by the nature of the hypothesis on the one hand, and by the character of the data on the other. For example, a man is found dead in a room. Suppose it be decided that he came to his death by a gunshot wound in the head such that death must have been near-instantaneous. Suppose also that no weapon can be found on the premises and that signs of a struggle are in evidence. The hypothesis of "suicide" is then inconsistent with, *i.e.*, it fails to explain, many of the relevant facts. Consider, to take another illustration, the nebular hypothesis of Kant and Laplace. For a time this hypothesis seemed to account for the motions of all the then-known bodies of the solar system. However, with the discovery of the retrograde movement of the eighth moon of Jupitur, another and relevant fact intruded which could not be accommodated to the hypothesis, in consequence of which the hypothesis was seriously questioned.

(3) Lastly, a hypothesis should be as *simple* as possible; or, if two or more rival hypotheses seem equally well to account for the facts, then, other things being equal, the simplest of them is the truer. By simplicity is meant *logical* simplicity; one hypothesis is simpler than another, not because it is more familiar or more easily learned than the other, but only when the number of independent elements contained in it are fewer than those contained in or implied by the other. Thus the concepts of plane geometry are simpler than those of solid geometry, because the former involve configurations in but two dimensions whereas the latter involve configurations in three dimensions. Thus the law of gravitation is simpler than the Ptolemaic

system of concepts, since the latter postulates a special hypothesis to account for each of the apparent motions of the bodies of the solar system.

Simplicity possesses also a second meaning. While two hypotheses may both account for a given domain of facts, one may account for a wider range of facts than the other. The former will then be simpler than and, therefore, preferable to the other. Thus the heliocentric theory, especially as developed by Newton, is systematically simpler than the theory of Ptolemy. We can account for the succession of day and night and the seasons, for solar and lunar eclipses, for the phases of the moon and the interior planets, for the behavior of gyroscopes, for the flattening of the earth at the poles, for the precession of the equinoxes, and for other events, in terms of the fundamental concepts of the heliocentric theory. While the Ptolemaic system of concepts can also be made to account for these phenomena, special hypotheses must be postulated in order to explain many of them, and many of these postulates are logically independent of the type of order taken as fundamental.

Indeed, it is this systematic simplicity which is sought in advanced stages of scientific inquiry. Unless we remember this, many changes now taking place in science will seem arbitrary. For changes in theory are often made for the sole purpose of finding some more general hypothesis which will explain what was theretofore explained only by two or more independent hypotheses. This is the chief advantage of Einsteinian over earlier hypotheses in physics. When it is declared that we should prefer the simpler of two theories, it is always systematic simplicity that is meant.

Yet it is often difficult and sometimes even impossible to differentiate between the relative systematic simplicity of two hypotheses at an advanced stage of scientific inquiry. Is the Schrödinger wave theory more or less simple than the Heisenberg matrix theory of the atom? In case we can not decide, we must allow for an irrational esthetic element in our choice between them. But while there is thus an element of arbitrariness in our choice between rival theories, the arbitrariness is limited, for the theory chosen is still subject to the other criteria of verification. Only in those cases where *all* criteria fail us can we truly say that the rival hypotheses are all equally verified or unverified and hence are equally probable.

GALILEO: PIONEER IN PHYSICS[1]

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FIFTY years ago this month, a highly interesting group of scholars gathered in the city of Padua. The occasion was the three hundredth anniversary of Galileo's first lecture before the already ancient university of that city. Delegates were present from the leading intellectual centers of Europe. Cambridge University was represented by Sir George Darwin, son of Charles Darwin, the great naturalist, and father of Sir Charles Darwin, now director of the National Physical Laboratory. Honorary degrees were conferred upon such men of science as Helmholtz, Kelvin, Tisserand, Schiaparelli, and our fellow countryman, Simon Newcomb. The public addresses were in every way worthy of the man they celebrated—the last of the great Italians.

Naturally one's curiosity is aroused to learn just what any man could possibly have done in physical science three centuries ago to deserve such long remembrance. The answer to this question most of you know as well as I; some of you much better than I; for, in all the annals of science, no man has so often been tried before the public by historians and astronomers, as has Galileo. In the time allotted to me, I am hoping to say only a few words about the surroundings under which the boy grew into manhood, then a few more words about the mode in which he introduced the experimental and quantitative method, thereby creating the science of modern physics.

Let us step back just five short lifetimes of three score years and ten. We find ourselves at the close of the sixteenth century and near the end of Queen Elizabeth's reign. The first great wave of the Reformation has passed, but the final military struggle between the Catholics and the Protestants—generally known as the Thirty Years War—has not yet begun. This is the period when "divinity doth hedge a king," when natural science is limited to medicine and physical science to astronomy; when philosophy is still in the saddle and scholarship is confined to the clergy. The system of Ptolemy has been overthrown; but that of Copernicus has not yet been established.

It was under circumstances such as these that Galileo was ushered into this stormy world on the fifteenth of February, 1564, at the little city of Pisa. He had chosen good parents to be born of. The visitor in Florence who enters the large door of the church of Santa Croce finds himself standing over a marble slab covering the grave of a Galileo who had distinguished himself in medicine some two hundred years before the advent of his famous descendant. The father of our Galileo was no ordinary man. For he was well known, not only as one who did his own thinking, but also as a composer of madrigals, an authority on counterpoint, a skilful performer on the lute and a historian of ancient music. The originals of his more important works are to be found, even today, in our Library of Congress. Just now the father had fallen upon hard times: and was earning a scant livelihood for his family by giving music lessons.

[1] From the symposium on "Natural Philosophy" commemorating the 300th anniversary of Newton's birth and Galileo's death which was to have been presented at the New York meeting of the American Association for the Advancement of Science. Other papers of the symposium will appear in later numbers of this magazine.

It is not surprising that a lad, brought up with this background, should find himself a student in the University of Pisa at the age of seventeen. Here at the request of his father he enrolled as a student of medicine; and listened to the famous physician and botanist, Cesalpino. The major portion of his time was given to the doubtless dull task of reading what Hippocrates and Galen had said; but the boy's natural bent, towards mathematics and experiment, was too strong to allow him to pursue any farther the medicine of that day. And so, much against the wishes of his father, he shifted his attention to Euclid and Archimedes, designed a hydrostatic balance and played with the determination of certain centers of gravity. It was exactly at this time that Maurolycus published a beautiful Latin translation of the works of Archimedes, a volume which, we may be sure, Galileo eagerly devoured much in the same fashion in which our late friend and genial spirit, A. G. Webster, brought himself up on *Thomson and Tait* and then proceeded to write a much better book on the same subject.

These early mathematical studies, made in Florence, occupied a good part of the three years following Galileo's departure from the University of Pisa in 1585. And they served him well. For they not only brought him into contact with Father Clavio and the Marquis del Monte, two of the leading mathematicians of Italy, but they earned for him a lectureship in mathematics at the university from which he had so recently withdrawn—the university where he had just shown himself to be a radical in philosophy and a disputant of the first order. It was during this second period of his residence at Pisa that he took up the most serious pursuit of his life—the study of dynamics. Here he eagerly adopted the maxim of Aristotle which, in its medieval form, read *Ignorato motu ignoratur natura.* Here also he displayed his faith in experiment rather than in peripatetic philosophy. There was no thought, even in these early years, of swallowing Aristotle whole. The famous demonstration at the Leaning Tower, about which so much has been written and so little known, also belongs to this period.[2]

What is most certain about these few years at Pisa is that Galileo's frank expression of opinion had made him *persona non grata* to some of his colleagues; so that he was happy to accept, in 1592, the chair of mathematics in the University of Padua—an institution which was, even then, older than Harvard University now is. His eighteen years in this renowned seat of learning were a period of uninterrupted success; "the happiest of all my life" he calls them.

His lectures at this time did not deviate much from those given in other Italian universities. His principal topics were *The Elements* of Euclid, *The Sphere,* equivalent to our astronomy, *The Almagest* of Ptolemy, *Fortifications, Perspectiva,* which we now call *Optics,* and *Mechanics.*

The Copernican system was then a recent invention. That it was well known to Galileo and was accepted by him is shown by his private correspondence. "Why then," you ask, "did he not lecture upon it?" One can only guess that a young man of 28 is not anxious to borrow trouble or to share such derision as had recently been heaped upon Copernicus. Kepler's *nova* which flashed out brighter than *Jupiter* in 1604 gave Galileo an excellent oppor-

[2] More than twenty years ago, Cajori and Partridge showed by careful search that, if Galileo ever allowed two bodies, one heavier than the other, to fall from this tower, neither he nor any one of the witnesses present has left the slightest written account of the experiment. Professor Lane Cooper has indeed written a hundred-page volume in order to establish a thoroughly agnostic attitude of mind toward all stories and pictures of this dramatic event.

tunity to break down the Aristotelian view of the incorruptibility of the heavens; but he exercised great self control and continued to expound the Ptolemaic system until the invention of the telescope in 1609.

One happy feature of academic life at Padua was that often a group of students working with some particular professor would live in the same house with him. Galileo lodged and boarded such a group of students. Some of these he employed in his workshop where his geometrical compass and other pieces of apparatus were manufactured. It is therefore, not surprising that, immediately after learning of the invention of a telescope in Holland, he should ask himself what the optical combinations must be; or that he should at once put together a plano-convex and a plano-concave lens into what we would now call a long focus field glass. Nor is it surprising that in rapid succession he discovered the mountainous character of the Moon's surface, the first four satellites of Jupiter, the "triple nature" of Saturn, the phases of Venus and the spots on the Sun. The year 1609—eleven years before the landing of the Pilgrim Fathers—will long be remembered not only for the invention of the telescope, but also for the announcement, by John Kepler, of his first two laws—laws which, in a certain sense, completed the geometrical theory of our solar system. The mention of Kepler's name reminds one of a surprising and unfortunate trait in the character (or perhaps in the mind) of Galileo. I refer to the fact that he never appreciated the monumental discoveries of Kepler.

The recent revelations of the telescope which Galileo had announced in the *Sidereal Messenger* were fraught with many long results of personal significance. First of these was a generous increase in salary. The second was a cordial invitation to return to his native Tuscany as Philosopher and Mathematician to the ruling family—the Medici. Needless to say these two results were much more acceptable than the long train which followed.

In 1610 he returned from Padua to Florence where the remaining 32 years of his life were spent in observation, experiment and reflection, interrupted only by brief visits to Rome. The results of these labors are recorded, as you like, either in the splendid 20 quarto volumes of Favaro's National Edition or in Galileo's three outstanding books, namely, *The Saggiatore, The Dialogue on the Two Astronomical Systems,* and *The Dialogue on Two New Sciences.*

The distance between Florence and Rome is not very different from that between New York and Baltimore. Covered by train or motor car, it is merely a pleasant jaunt. But, for Galileo, who never set foot outside of Italy, in spite of the fact that he had opened the doors of the heavens and had roamed the universe, this journey was a considerable undertaking. He made the round-trip six times; each excursion being an event of such importance that the rest of his story may, perhaps be told in terms of these journeys.

I. An early first visit need not detain us; for it was made by the twenty-two year old student of mathematics in order to discuss with Fathers Clavio, Moletti and Valerio—three able mathematicians—certain problems upon which he and they had been working.

II. In the spring of 1611, our astronomer—now a mature man of forty-seven—made his second trip in order to exhibit to the pontifical court some of his newly discovered celestial objects. In Rome, he was the guest of the Tuscan ambassador at the Medici palace on the Pincian Hill. His telescope was set up in the nearby gardens of the Quirinal palace which was, at that time, the summer home of the Pope.

Here a group of able cardinals and

monsignori saw the mountains on the Moon, the phases of Venus, the four moons of Jupiter and, by day, the spots on the Sun. The result was that, within the next two years, Galileo was called upon, by men high in church and state, to explain the "evident" contradiction between Science and Scripture. His replies to all these queries are marked by one essential thought, namely, "The Bible teaches us how to go to heaven; not how the heavens go." Science and the Scriptures tell two independent stories. His own famous words are "*La scienza nè sopra nè sotto la fede, ma fuori della fede.*"

III. Again four years later, in December of 1615, we find him on his third visit to Rome, urged this time by the desire to clear himself of charges which two Dominican monks in Florence had made to the Inquisition. This time he was cordially welcomed and eagerly listened to by del Monte and Bellarmini, two important cardinals; but they gave him semi-official warning not to indulge in theology. In particular, he was advised not to "hold, teach or defend" the rotating earth or the fixed sun. Whether or not Galileo agreed to these conditions is not certainly known. In any event, this conference is generally known as his "first trial."

Rejoicing that no abjuration had been required, he returned to his home at Bellosguardo, a suburb of Florence, and entered upon a seven-year period of uninterrupted work.

IV. Then comes his fourth trip in 1624—about the time when the Pilgrim Fathers had fairly established themselves on the coast of Massachusetts. Father Grassi, a Jesuit astronomer in the Collegio Romano, had published in 1619 a small volume in which he opposed Gallileo's theory of comets and indulged in violent abuse of its author and of his school. The object of this fourth visit was to publish, through the Academy of the Lincei, a reply to Father Grassi. This reply, which he called *Il Saggiatore*, is a tremendously clever piece of polemic, abounding in wit and humor. It was dedicated to his long time friend, Cardinal Barberini, now become Pope Urban VIII. One can easily imagine how little a publication of this kind enhanced the credit of the Florentine astronomer among the Jesuits.

V. Six years filled with labor and illness now elapse before the fifth journey to Rome is undertaken. The work accomplished during this interval was the preparation and composition of the *Dialogue on the Copernican and Ptolemaic Systems*, which for elegance of style and clearness of exposition remains unsurpassed. The purpose of this trip was to obtain an *imprimatur* for this *Dialogue*. He travelled by court litter and was handsomely entertained on the Pincian Hill at the home of the Tuscan ambassador. His friend Urban VIII gave him not only six lengthy audiences but also a pension for his son. After long delay, the *imprimatur* was granted but only with certain humiliating conditions. The details are too long to be recited here. Suffice it to say that the book issued from the press at Florence in January of 1632. Its sale was prohibited in the following August.

VI. In October of the same year, the Inquisition summoned Galileo to Rome, where he arrived in February of 1633. Previous trips were easy when compared with this one which was his sixth and last; for it was made in midwinter by a man of three score and ten, in feeble health, carried in a litter which was perhaps none too gentle. Once more he was the guest of Nicolini the Tuscan ambassador.

The charge against Galileo, at this second trial, was of course that he had defied the command of the Holy Office. This command was that he give up his belief in the double motion of the earth,

that is, its rotation on its axis and its revolution about the sun. On the 22d of June, 1633—a memorable day—he was forced, under threat of torture, into the great hall of the Inquisition, attached to the church of *Santa Maria sopra Minerva* and was there made to read his recantation.

Many various opinions have been expressed, as you all know, concerning this recantation. My guess is that Galileo wisely acted upon the advice of his friend and host, Niccolini, who urged him to accede to the orders of the Inquisition and to say to them, not in so many words, but virtually and in his own mind "Well, if *you* say that the earth does not move, it must be so! And there's an end of the whole matter."

Can anyone believe that this aged scholar, travelling along his *via dolorosa,* had forgotten what happened to that courageous soul, Giordano Bruno, when, only a few years back and only a few city blocks away, the flames consumed his poor body? Does anyone imagine that Galileo had forgotten his first love among the sciences? Is it possible that the unfinished work on dynamics, upon which he was to spend the remaining years of his life, had completely slipped his mind? He had given the Inquisition a respectful acquiescence; but the matter of inner assent was his own affair. Obviously he was neither hero nor martyr of science in the ordinary acceptation of those terms. I like to think of this second trial not as a battle between science and religion but as a contest between science and Aristotelianism. I entertain also a high respect for that ancient Chinese proverb which maintains that a wise man adapts himself to circumstances as water shapes itself to the vessel which contains it.

July of 1633 finds this lonely man starting north again defeated but undaunted. This time he stops on the way, at Siena, to spend a few months with his trusted friend, Archbishop Piccolomini. So that it was not until December of 1633 that he completed his last trip to Rome and reached his little villa at Arcetri where, in strict seclusion, he spent the years that were left.

But these years, during which the greatest living man of science was confined at home by decree of the Holy Office, as well as by illness and by old age, make up one of the remarkable periods of his life. "Here it was," says the young Milton just out of Christ's College, Cambridge, "that I found and visited the famous Galileo grown old, a prisoner to the Inquisition for thinking in Astronomy otherwise than the Franciscan and Dominican licensers of thought." Here in his declining years, not many yards away from the little convent of San Matteo where his two daughters had taken the veil; here where nearly all his family had perished in the recent plague; here, in humiliating and discouraging circumstances, he takes up the science to which his early years were devoted, the science to which his contributions showed the highest originality and the utmost importance.

His interest in mechanics, which appears to have been life-long and unbroken, culminated in the *Two New Sciences*—the work for which he will probably be longest remembered. The entire volume is based upon the assumption that terrestrial and astronomical phenomena are to be explained in mechanical terms—an assumption which has been out of date since the close of the nineteenth century, but one which many twentieth century physicists admit to have been helpful in its day.

Harry Lauder, you know, insists that World War No. 1 was won mainly by the Scotch regiments, but admits that the French, English and Americans rendered important assistance.

This last book of Galileo's is in the form of a dialogue which offers great

freedom to introduce new topics and permits the easy give-and-take of an after-dinner group in a club corner. The early part of the work is devoted to what we now call strength of materials, bending moments of beams and digressions upon such various topics as the harmonies of the major chord, the definition of an infinite quantity and the velocity of light. So far as I have been able to learn, his picture of an infinite quantity, as one which is so large that a part of it can be placed into a one-to-one correspondence with the whole of it, is original and also basal to the later and more complete view of Cantor, Bolzano and Dedekind. His method of measuring the speed of light by sending a luminous pulse to a distant observer to be returned by him is of course valid only in principle; but the principle is precisely the one which was so admirably perfected by Fizeau and the late Professor Michelson.

The latter part of the book is given over to a description of what was then known as "local motion"—a striking term which harks back to ancient days when *motion* meant change; and hence *local* motion meant change of *position*. The idea appears to survive in our word *locomotive*. Galileo aims to describe only those motions which occur in nature; so he begins with freely falling bodies; "dilutes" gravity by use of an inclined plane; proves by experiment the constancy of gravity for a bronze ball; and then by use of a hollow pendulum establishes the remarkable fact that gravity is constant for *all* substances. *Uniformly* accelerated motion having been identified with *naturally* accelerated motion, the other laws of falling bodies follow easily and immediately.

The vector idea he introduced into mechanics by use of the inclined plane; and by comparing the *increasing* momentum of a body rolling down such a plane with its *constant* momentum as it rolls along a horizontal plane, he distinguished between the behaviour of a body which is acted upon by a force and of one which is free from force. He thus led directly to our modern definition of force as the rate of change of momentum. But the idea of a body under no force moving with uniform momentum is, of course, nothing else than Newton's First Law of Motion. His introduction of time as a variable which can be measured and represented by a distance laid off on an axis is, so far as I know, an entirely new and important step.

The last chapter of the *Two New Sciences* is devoted to the motion of projectiles. The maximum range *in vacuo* is quickly established as one having an elevation of 45°; but most important of all is his remark that "such motions and velocities as these combine without altering, disturbing or hindering each other." This statement is such a close approximation to the second law that Newton, in the *Principia*, distinctly credits Galileo with the discovery of the first two laws of motion, reserving for himself only the third. Galileo's complete abandonment of all metaphysical considerations, his refusal to ask *why* bodies fall and his insistance upon discovering *how* they fall has made this Italian physicist a model for all subsequent investigators.

In conclusion it may be said that the science of mechanics owes to this pioneer not only the first two laws of motion but also the modern definition of force as the rate of change of momentum. Just how new and radical these ideas were can be conceived only by one who has acquainted himself with the then current peripatetic notions on the same subject.

The distinction between *mass* and *weight* was a later step, reserved for Huygens. *Impulsive forces* and *tides* were also beyond the ken of Galileo. These two puzzles were first robbed of their mystery by Galileo's great suc-

cessor whose birthday is being celebrated this year.

In this connection, may I say that the contrast between Newton and Galileo is not altogether pleasing. The Italian was born under circumstances which bordered on poverty and spent his boyhood in the narrow confines of the city; the Englishman began life in affluent surroundings and roamed freely over the lovely countryside of Lincolnshire. The one found a university career possible only by the endurance of great privation and left it incomplete because of unpleasant associations; the other enjoyed fellowship and freedom, companionship and comfort in one of the leading institutions of his country. The one found his work opposed by the church and plagiarized by his fellow countrymen; the other was rewarded by a distinguished professorship and honored by political preferment. Late in life one is still hounded by the church; the other is elevated to the presidency of the leading scientific academy of the world.

Yet, with all these odds against him, Galileo spent his life in the study of motion, a subject which had been left untouched by his great predecessors, Euclid, Archimedes and Apollonius. The path which our pioneer cut through the forest, 300 years ago, was precisely the one followed by Huygens and Newton—the one which led unerringly to that field which is now cultivated under the name of physical science.

Responsibility rests upon science as never before. In our present crisis we depend mainly upon physics and biology. Our fate is in the hands of the young manhood of the United Nations. They are employing three great powers *science*, *economics* and *politics*. Can anyone doubt that they will reestablish the freedom of international thought and individual enterprise in both hemispheres?

VISION, HEARING AND AERONAUTICAL DESIGN

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It is principally through the sense of vision that pilots are aware of the nature of terrain, weather conditions, the terrestrial orientation of their aircraft, and the position and movements of enemy planes. Even so-called "blind flying" is primarily a visual function. Here the "contact" is transferred from the horizon and ground objects to the special instruments upon the panel. Hearing likewise is of critical importance to military flyers in that command information and assistance from ground control stations must be audible over the communication system. Also intercommunication systems within aircraft must function as the principal means of maintaining prompt and coordinated action of members of air crews in carrying out military missions effectively. These facts are generally known and accepted by plane designers. However, engineering success in providing for ease of seeing and ease of hearing is quite variable, and these basic pilot requirements merit our continued attention.

Take, for example, the almost complete blanking off from vision of an area directly ahead of the pilot when a plane changes its normal flight attitude to a

landing attitude. This is particularly vicious in the case of fighter aircraft with large air-cooled engines in the nose of the ship; and the condition has resulted in a great number of avoidable landing, taxiing, and take-off accidents. Aircraft carrier accidents have undoubtedly resulted from this blanked off area, in spite of the fact that a landing signal officer is supposed to direct the landing properly. Mirror reflections of the area immediately ahead of the plane could be provided. Tricycle landing gear on some few aircraft have done much to benefit this blindness due to radical change in plane attitude.

Engineers are no doubt aware of the desirability of placing pilots, observers and gunners as near as possible to the transparent panels through which they must get their visual impressions. The nearer the eye is to the window, the larger the visual field that can be seen through it, or for a given angular field, the smaller the window needed. The ordinary spectacle lens one and a half inches in diameter gives the wearer an uninterrupted view of almost 90°. Close proximity to airplane windows also makes for clear visual fields; (1) it is easier to provide the requisite transparent area free from obstructing pillars, panel joints, and opaque accessories; (2) marks, specks, and scratches on the window surfaces are less bothersome because they are out of focus; and (3) when near the window, the observer's head makes an area of shadow which is helpful, particularly at night, since it blocks off reflections from the inner surface.

The Gunner's Visual Problem

The position of gunners in relation to windows is especially worthy of consideration. We may take a hypothetical set of measurements for discussion. The gunner's eye must be about nine inches behind the gun sight; the sight is twenty inches from the aiming panel; the gunner's seat is therefore placed against the back wall of the turret, and the space in front of him is well filled with gun supporting and operating structures. The aiming panel is a beautifully clear, optically perfect surface 14 × 14 inches. The engineers are to be congratulated on this window, but not on the position of the gunner. For him the situation resembles that met in tunnel vision. His eyes are 29 inches away from this superb window which can provide him with a view of only 28° of the full 60° to 90° that are so critically needed.

The aiming panel must of course be well mounted, and this calls for a rather heavy metal frame. Sometimes it is as much as two inches wide. Other small, usually curved windows border the aiming panel, and each of these must have or share a frame with adjoining windows or wall structures. When the guns are in front of the gunner, sections of the mounting structure, brackets, electrical switches, etc., frequently have locations which obscure portions of the windows from the gunner's eyes. The total effect is a lattice windom with the lattice predominating over the clear space in some instances. From the gunner's view, through a particular panel, a total of only 25 per cent. is unobstructed to binocular vision; 53 per cent. is totally obstructed; 22 per cent. is obstructed for one eye. Juliet could manage to get an eye full of Romeo through a lattice window, but our gunner is not cast in the role of a shy lover. For him the irregular lattice is a hazard to vision and life. It is true enough that through the lattice he can see a lot of landscape as he looks from one opening to another. What he needs to see, however, is moving planes. When his eyes catch sight of one, they try to follow it. This is done by a special kind of coordination in the action of eye muscles and is known as pursuit eye movement. The eye actively

glides along at a rate set by the visual target and appropriate to keep it in clearest possible view on the fovea. Visibility of the moving target is essential for this type of seeing. Whenever the moving target momentarily disappears, as happens when it passes behind opaque lattice areas, the pursuit movement is immediately stopped. The eye jumps to the far edge of the obstruction and waits. When the target emerges, a new pursuit movement must be organized by the nervous system. This necessarily costs an average delay of fifteen hundredths of a precious second before clear pursuit vision can be reestablished. The gunner is of course not completely blind during this interval, but his visual efficiency on the moving target is hampered by every opaque gap across which he is compelled to operate.

In turrets where the guns may be mounted at the sides and rather low down, it should be possible to reduce the amount of structure in front of the gunner and to bring him forward much nearer the front panel. This will increase his angle of uninterrupted view, make visual pursuit of his targets easier, and reduce the blinding effect from the flashes of his own guns.

Vision Inside the Cockpit

Inside the cockpit we usually observe a confusing multiplicity of instruments and the lack of a suitable grouping of essential flying instruments according to a well planned pattern for visual perception. For purposes of night flying where visual function is largely dependent upon maintenance of dark-adaptation of the eye, instrument panels in general are subject to the following serious faults:

(1) There is too large an illuminated area. Instruments which are referred to infrequently are constantly illuminated.

(2) The color of the transmitted or reflected light from these instruments is usually not of the spectral band least disturbing to night vision.

(3) Intensity as well as total area of illumination is considerably too high. This is usually a criticism equally applicable to direct or indirect lighting, radio-luminous, or fluorescent marked instruments. The only light which can be controlled easily both as to spectral character and brightness level is indirect red light. The use of a spectral red whose transmission band lies in the region of 600 millimicrons is recommended for instrument lighting. The intensity of such light may be permitted to vary considerably without adverse effect upon night vision.

Transparent cockpit enclosures, although of fairly clear optical plastic, discolor with exposure to sunlight; some of them become finely checked due to temperature changes and vibration. Nearly all of them are capable of being scratched too easily, and the result is interference with vision. Measurements of visibility through plastic windows, compared with bullet-proof glass and with open cockpit view, show that the glass produces a slight loss and that the loss from the plastic may be five or six times as much. Flat panes consistently provide better visibility than do curved plastic surfaces, but they may also give an increased drag. A compromise must be made between visibility and aerodynamic considerations. Rapid strides in development of better plastics are being made, and it should be possible soon to mold transparent cockpit enclosures of better grades of optical plastics in one piece. Surface hardening of such molded parts is desirable. Close attention should be given to reducing inside reflections which are particularly troublesome from concave surfaces.

In military aircraft we often find that vision forward and to either side is fairly well provided for but that even though the pilot may have the usual

well-developed rubber neck, he is handicapped by certain design features of his plane in seeing what may be above or aft. It is often forgotten that in actual combat pilots refuse to leave the "greenhouse" closed and must therefore use goggles. Any fixed aperture made available for the pilot's face should not be too small to permit use by a bespectacled or goggled aviator.

Airsickness and Vision

Airsickness of passengers and crew may result from unavoidable motion stimulation of the vestibular mechanism of the ear, from rapidly changing gravitational forces acting on viscera, muscles, and joints, and from apprehension and past unhappy memories of plane travel. All of these upsetting stimuli are as a rule less disturbing if those affected can see out and establish visual contact with the horizon, with cloud formations, and with the ground scene below. We should remember the old instructions to novices in flying, "Never look at the up wing; watch the down wing." Many troop-carrying glider craft afford virtually no opportunity to look out and establish visual contact beyond the plane. To arrive at the scene of battle with a load of thoroughly ill troops contributes nothing to fighting morale and effectiveness. A part of the answer to this difficulty is—don't require passengers and crew to fly blind.

Hearing Suffers More than Sight

The ears more than the eyes are subjected to environmental stress through flying. It seems to be true of modern aviation that every time the engineers increase the power and speed of our airplanes, the ears of the pilots take a greater beating. Although the ear is a magnificent little mechanism—the most intricate mechanical structure in the human body—it is a rather delicate device and one which seems ill designed for modern war. But the ear has gone to war, along with the rest of the soldier, and we are compelled to admire the service it renders in the face of acoustic stress.

Airplanes have always been noisy, and they are becoming noisier. A thousand horsepower fed into a propeller is able to agitate the atmosphere in a thunderous manner, and when the engine delivers two thousand horsepower the din is doubled, or actually more than doubled, because as the tip speed of the propeller increases a larger proportion of its driving energy is converted into sound. When this energy pounds on the ear, it is striking a mechanism so sensitive that less than one quintillionth of a horsepower is needed to produce a faint sensation of hearing. In addition, more horsepower means more speed and hence more turbulence about the ship. It is this turbulence of the slip stream over the wings and about the fuselage that produces the distressing, high-frequency random noises which sound like a mighty "shhhhhh." In some respects the noise from the turbulence about the plane is more of a problem than is the noise from the propeller itself. This is demonstrated in planes which do not have propellers. Contrary to popular notions, the interior of a glider plane moving at about 150 miles per hour is a very noisy place. The noise level is about 115 decibels, and conversation in such a place is difficult, if not impossible.

In any really fast moving vehicle the noise is random, that is to say, all frequencies of the spectrum are present. When we listen on the ground to a plane high overhead we hear only the low frequencies of the propeller. But inside the plane it is different; there we hear all frequencies added together at once, producing a noise which is to sound what white light is to light. And as a general rule, the greater the speed, the "whiter" the noise. Also as a general rule, the

whiter the noise, the more objectionable it is to the ear. "White" noise is objectionable for three reasons: it is disagreeable, it produces temporary deafness, and it spoils communications.

That white noise is annoying needs little argument. No one has been found who really enjoys it. It is true, however, that our attempts to prove that long exposure to intense airplane noise is damaging to human efficiency have produced essentially negative results. When adequately motivated, a man can code a message, add columns of figures, coordinate his movements, react to a signal, etc., about as well after eight hours in a noise of 115 decibels as after a similar period in the quiet. Despite this remarkable experimental result, our subjects all report that they find the noise unpleasant, and they are happy when it is turned off.

Temporary Deafness

That airplane noise produces deafness is a well known fact. In normal ears this deafness shows two characteristics: it is restricted more or less to the high frequencies, and fortunately, it is usually temporary. After eight hours in an airplane noise of 115 decibels, the normal ear shows a hearing loss of about 40 decibels in the region of 4,000 cycles. It has sometimes been supposed that low-frequency airplane noise produces high-frequency hearing loss. On the contrary, it is the high-frequency components of the noise that produce the high-frequency loss. The ear, for some unknown reason, is more vulnerable at these high frequencies.

Recovery from a 40-decibel hearing loss usually occurs in about 24 hours. The recovery is rapid at first and then proceeds more slowly. About half of the loss is regained by a normal ear in the first three hours after exposure. Some ears apparently do not have this power of recovery, and repeated exposure to noise leaves them permanently deafened. Although we usually blame the noise for such deafness, there is a question as to whether the ear itself is not the real culprit. At any rate, many ears appear to develop high-frequency deafness without excessive exposure to intense noise.

Improvement of Communications

The most important practical effect of airplane noise is the masking of communications. Not only is conversation impossible in some planes, but even over radio and interphone speech signals are often masked beyond recognition. Articulation tests have shown that with much of our standard military interphone equipment a listener is able to understand only about 50 per cent. of the words spoken in the presence of an airplane noise of 120 decibels. Over the same interphones more than 95 per cent. of the words are understood when there is no ambient noise present to interfere with the speech.

The difficulty of communicating under the handicap of airplane noise calls for vigorous remedies. Constructive measures can be applied in three general directions:

First, the plane can be quieted to some extent, either by improved aeronautical design or by the application of sound absorbent materials. Acoustic treatment that is light enough to be tolerated in a plane does not appreciably reduce the overall noise level. It does, however, change the spectrum of the noise by reducing the intensity of the high-frequency components. Hence, the noise in an acoustically treated plane is less "white" and therefore less bothersome than the noise in an untreated plane. Tests have shown that, for the same overall sound intensity, conversation person-to-person is relatively easy in a treated plane but quite impossible in an untreated one.

The second remedy calls for an im-

provement in the response characteristics of the communication equipment itself, especially of the microphones and earphones. A loud noise does not interfere with intelligibility nearly so much when instruments of high fidelity are used. But with microphones that have non-linear distortion and with earphones that at some frequencies are sharply resonant, the effect of an airplane noise of 120 decibels is to reduce the intelligibility of speech by 30 to 40 per cent. High-fidelity equipment is not yet being widely used in airplanes, although a few major improvements are now in process. Complete overall high fidelity from microphone to earphone must be achieved if speech is to be transmitted to and from our most modern airplanes.

The third remedy called for by the noise problem is the shielding of the microphone and the earphones from the noise. The oxygen mask could be so designed as to shield the microphone from the ambient racket, but many otherwise excellent masks suffer from acoustic defects. This problem is now under study, and improved noise shields for hand-held microphones are being developed. The earphones and the ear of the listener can be shielded from the airplane noise by means of an acoustic socket designed to provide a tight seal against the side of the head. In present military equipment this provision has been neglected, but improved devices are now in production. Some of these ear protectors serve to reduce the unwanted sound in the aviator's ear by 20 to 50 decibels.

Conclusions

In general, it can be said that the problems raised by intense ambient noise are serious but not insoluble. Judicious use of sound treatment in the plane, conversion to high-fidelity microphones and earphones, and the development of acoustic devices to shield the mouth and the ears of the personnel will permit the aviator to carry on in the best noises which the aeronautical engineers are now planning to produce.

The flying and efficient fighting of modern planes is largely dependent on the special sense of vision. The eyes fortunately suffer no great decrement in function from the swift movement or high and changing elevation of the airplane. Vision is adequate to the basic task assigned to flying personnel. The chief difficulty is in providing for optimal visibility through the structures of the plane and for continuous visual check on the environment surrounding it in both day and night flying. Ideal visual conditions are not wholly attainable because of aerodynamic and structural necessities. However, we should make the effort to gain all possible visual advantages. The problem is a continuing one and offers important strategic possibilities.

Both seeing and hearing, if accompanied by prolonged attentive effort, especially under conditions of unfavorable plane design, are capable of contributing to pilot and air crew fatigue and loss of efficiency. It has been proved worthwhile to give the airplane engine an adequate combustive mixture by supercharging and to pay special attention to protecting the oil in the engine against "foaming" at high altitudes and reduced barometric pressures. It is proving and will prove worthwhile to consider the flyer's eyes and ears and the rest of his very mortal body and to reduce in every possible way the tendency to physiologic and psychologic "foaming" in him.

MEDICINE AND THE COMMUNITY

By Dr. LEO LOEB

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ALL human beings face the struggle with nature for the material goods necessary for the maintenance of life, bodily health, and the avoidance of pain and premature death, for the understanding of the physical and biological laws underlying the interaction between organisms and their environment, which in the widest sense comprises the universe. But in addition, they face difficulties and obstacles in their social life, in competition with other human beings for material and psychical goods, in conflicts between different systems of tradition, suggestion and thought. Thus they have to face not only the natural struggle, but also the social struggle, and the latter is perhaps the more subtle and far reaching one as far as individual satisfactions, happiness or unhappiness are concerned. Here, they face the mental pain caused by doubts as to their justification or guilt in these conflicts, caused also by the suffering they avoidably or unavoidably inflict on others and the suffering which is inflicted on themselves, and here too they face the necessity of maintaining their personality in balance with that of others.

Confronted by the social struggle, the investigator in the biological and medical sciences, like other human beings, cannot help but make observations and in a certain respect even carry on experiments in regard to the more general problems of living, which affect him both as an individual and as a social being; indeed life itself is but a series of consecutive experiments. However, not infrequently one meets eminent men of science who doubt the advisability of students of the exact physical or of the experimental biological sciences of giving their attention to the analysis of social phenomena in which the accuracy of the more basic sciences can apparently not be achieved. But our observations and conclusions here, as in the more exact sciences, may be true or false, and the criteria which are used for testing the truth are the same as those used in science.

There are others who are critical of such studies, because they may lead perhaps to the formulation of abstract principles, playthings of the mind, but are quite incapable of meeting directly the pressing needs in our social life. Yet true thoughts, even if they are not directly applicable to practical life, may be useful in suggesting directives for further thoughts, which ultimately will find application in daily life and which then will perhaps be found more far-reaching in their effects than the short cuts to near-ends desired by the more practically minded person. It may be that medicine, whose primary function it is to procure health, to delay death, and thus to aid man in his natural struggle, may take a leading part also in bringing about a mitigation of the severity of the social struggle.

Medicine in the course of time has dissociated itself from magic and has become an applied science of physiology, biochemistry and pathology. But it has progressed further: making use of psychology, it now treats the individual as a whole, his body as well as his mind. The interests of medicine continue to expand; the physical and psychical aspects of individuals can not be separated from their social background, from their customs, traditions, standards of social judgment and economic conditions. Medicine, therefore, includes in its sphere of inter-

est also sociology and makes use of the data this science has secured. And seeing further into the future, there may perhaps be a time when the physician will become the statesman, who, with the help of the engineer and economist, will direct the policies of whole communities, national and international, and when the statesman will essentially be a physician whose task it is to attend to the physical and mental health of the community. Thus medicine will be the science of man, applied to the maintenance of his physical and mental health, and it will then become evident that the problems of statesmanship will, to a considerable extent, be the same as those with which the physician has to deal in taking care of the individual; the statesman will, however, deal with the problems of the larger communities.

Such an extension of the function of the physician presupposes that it is possible to understand and in some degree foresee the action of individuals and of groups of individuals. But there are several criticisms which science in general, and medicine in particular, has to meet in this respect. It has been maintained that the action and attitudes of human beings are determined primarily by their genetic constitution and that inasmuch as no two individuals have the same genetic constitution, the actions of human beings cannot be foretold. Moreover, past experiences, which likewise influence human actions, differ in each individual. A science of human attitudes which could be practically applied, could not, therefore, be created. This conclusion is strengthened by the suspicion that knowledge in itself of a thing or relation will alter our attitude toward the latter and this again would render our actions unpredictable.

These arguments are not valid. All our bodily functions and structures are determined by genetic factors, yet we have been able to go very far in gaining an understanding of the structure and function of organs and tissues, as well as of the whole organism. Besides, it can be shown that human actions and attitudes, at least as far as they are of social significance, are to a great extent determined by environmental, psychical factors rather than by genetic factors, and that experiences, while different in each individual, consist in all of them of similar social-psychical elements. It is the suggestions which we received especially in our childhood, by means of words or actions from persons who impressed us deeply, or from those with whom we associated in play or study, which greatly influence our attitudes even in later life, and these potent suggestions, after all, are restricted in number and in kind. Thus we may expect that the more we study the behavior of individuals the more we shall find in it a certain lawfulness, the more we shall recognize the existence of definite types and combinations of types and of situations which make possible predictions as to the motives and probable actions under a given social environment, and the more we shall learn how these actions may be influenced and modified. As to the manner in which knowledge of a condition affects our attitude towards the latter, even this appears to be subject to precise laws, which it will be possible to formulate and make serviceable in everyday life.

But there is another objection which applies specifically to medicine. It has been maintained that medicine instead of improving the human species by creating a better stock, on the contrary, causes its deterioration by nurturing the weak and inferior beings and allowing them to propagate. Further, it has been said that science in creating an industrial civilization and making possible the production of luxuries and rapid means of communication, has softened the individual and rendered him less hardy and less able to withstand the hardships of life; it has made him super-

ficial, nervous and discontented. As to the criticism that the practice of medicine causes a deterioration of the human stock, no proof of this has been given; if it has occurred at all, the proof that it is due to the nurturing of the inferior members of the human society could be given only after elimination of unfavorable environmental factors. In regard to the breeding of a superior human race, it seems that medicine, as well as biology in general, faces a very complex problem. A human individual is a mosaic of an extremely large number of constituent parts, each of which may be inherited in its own specific manner. Some of these constituents determine physical functions of various kinds, which make for strength and resistance to disease, while others make for various types of weakness and physical inferiority, and the same complications exist in regard to mental and moral determiners of the individual. Back of the obvious advantages and strong points seen in an individual there may be hidden undiscovered shortcomings, and in a pattern in which inferiorities are quite patent there may be some fine and most desirable qualities which are not recognized. It is easy to breed race horses, good milk cows, chickens for egg laying; the selection is made here not for individuals that excel all around and have worth in their own right, but for a single separate characteristic, chosen by members of a strange, dominating species for their advantage. There is a further difficulty. Many of the less advantageous genetic factors are recessive and hence are covered up in persons who appear to have a good constitution. These individuals therefore continue to transmit these unfavorable characteristics to their offspring and the prevention of breeding by those in which the undesirable character becomes manifest would not very noticeably diminish the frequency of its occurrence among the remaining population. Furthermore, even if we were able to breed human beings selectively, it should be done not merely for the purpose of propagating the most perfect physical specimens, but especially with the view of creating beings sensitive to ethical values and capable of intellectual attainments. And lastly, by applying crude methods of breeding, similar to those used in animal breeding, there is the danger of lowering the significance of the individual and of psychical values which are of the greatest importance to all, and this might entail a depreciation of ethical standards more than offsetting any benefit which could be obtained by such a policy. If we consider this problem from the point of view of the pathologist, the number of diseases or of physical and mental defects in which genetic determiners are concerned is very great. There are, for instance, hereditary elements in the etiology of tuberculosis, of cancer; of hypertension and other diseases of the circulatory system; of abnormalities of carbohydrate metabolism (diabetes) and other metabolic deficiencies; there are hereditary elements also in the etiology of a variety of defects of the nervous system—such as some types of epilepsy; of defects of the eye, as those affecting the power of accommodation; of defects of the ear, of the teeth, and of various other organs. Which of these shortcomings in the genetic constitution would justify limitation of propagation? Might not a consistent and strict application of eugenic measures reduce the number of persons thought fit for parenthood to a small minority of the population?

Still, it must be conceded that there are conditions where it would be in the interest of the individuals themselves and of their possible offspring, as well as of future generations, that these persons be prevented from propagating. No conflict exists in such cases between the maintenance of the dignity of the individual and the interests of the com-

munity, which is composed of individuals—the latter being the essential reality. The methods used for this purpose must be humane and understanding.

The objections to science, and indirectly also to medicine, mentioned in the second place, are a criticism of civilization as it has developed mainly within the last hundred years. Science has provided the means of building factories and of rapid communications. Much time has been added to our life; we can make use of all kinds of products, which should satisfy our needs to a greater degree than has ever been possible previously in human history; new forms of entertainment have been provided on a much larger scale than was ever thought possible. Yet, it seems that happiness has not increased correspondingly. Although it is the physical sciences which are largely held responsible for these injurious changes, still, medicine is responsible indirectly, insofar as it has apparently made little attempt to prevent them.

However, it is not the contributions of science and medicine which are to blame for the deficiencies and unhealthy conditions in our civilization. What they have contributed is good; but these gifts have not been used altogether wisely, and the biologist, and above all the physician, in the future should take it upon himself, by his advice, to guard against the unwholesome application of modern technical improvements and inventions, which result in a loss of individual health of mind and body. Ultimately, these are questions of individual and social hygiene and they all belong, therefore, to the sphere of interest of the physician.

Yet it cannot be denied that while our civilization has eliminated much that was crude and even brutal in human relations, it has also caused a loss of the satisfactions which simple and sincere relations to other human beings and a quiet enjoyment of nature provide, and that there has developed much restlessness, an aggravated spirit of competition in all our activities, and consequently worry, jealousy, envy, intensified antagonisms and struggles, injurious attitudes affecting individuals as well as social groups and leading to intensified discontent and to loss of mental restfulness and poise. But, it is not only the technical advances which are responsible for these shortcomings in our civilization and for the decreased value attached to the simple psychical goods; they have merely aggravated something which has deeper roots in the organization of the individual and of the social groups.

In order to appreciate these difficulties, we may somewhat more fully discuss some of the conditions on which our bodily and mental satisfactions and, ultimately, therefore also our bodily and mental health depend. We wish to obtain material goods in order to maintain the life and bodily health of ourselves and of those depending upon us, and we also need simple and distinctive psychical goods in order to maintain our personality. The memories of the psychical satisfactions received from those around us, the principles of conduct transmitted to us, and the thoughts and emotions drawn from science, philosophy, literature and art, as well as our own thoughts and emotions based on our experiences and observations, constitute the store of our inner psychical goods. It is especially on the latter that the harmony, equilibrium and the strength of our personality depend as do also our initiative in thought and action, the absence of unnecessary fear and of undue suggestibility, the normal coordination of our muscles, and therefore the ability to give to others what is good in ourselves. In the end, all our bodily functions, such as those of the digestive and circulatory systems, are intimately connected with this psychical wellbeing. There are reciprocal relations on the one hand between the functions of the ner-

vous system and the endocrine organs, by which, in their interaction with the outer world, our psychical life is largely determined, and on the other hand the functions of our more elementary organ systems, the healthy action of the former influencing that of the latter and vice versa.

Simple psychical goods are the expression of understanding, appreciation and respect, of friendliness and affection which our fellow beings may give to us. They also consist in the peace of mind, poise and recovery from mental injury which we experience in the quiet of nature and in the wider thoughts and emotions given to us by science, literature, art and music; these ultimately are the expressions of the effects of nature and the doings of man on some minds which are peculiarly sensitive and which function as resonators. This need of simple psychical goods has its roots in our bodily organization, but added to these are our experiences, and the thoughts and emotions created in the natural and social struggle.

In contrast to the simple psychical goods the cultivation of distinctive psychical goods implies the accentuation of superiority or inferiority and of competition in human relations. There are distinctive psychical goods based on national and racial characteristics, fixed or modifiable and representing true or imaginary differences; there are others based on family and social caste differences; and a strong and, not rarely, destructive element of competition may enter even into the distribution of simple psychical goods, which thus are converted into individual distinctive psychical goods. As to the source and origin of our need for distinctive psychical goods, they also reach deep into our bodily organization; competition for distinctive psychical goods and states of superiority and inferiority are found in the social life of various species of animals. But what, in the social life of animals, is largely fixed and only slightly modifiable by means of conditioned reflexes, in man is controlled by suggestions and thought processes and, therefore, is to a much larger degree, changeable and subject to that which impresses us as free will.

The various forms of distinctive psychical goods give us the enjoyment of our superiority over others, a sense of elevation of our personality picture and thus also compensatory satisfactions for losses which we necessarily experience in life. By elevating our personality picture over that of others, they give us a feeling of security in the social and natural struggle, they make us less accessible to the will of others and prevent the results of excessive suggestibility and fear. They are much more effective in these respects than are simple psychical goods, but they also tend to separate individuals and groups from one another, to bring humiliation to many and to intensify greatly the severity of the social struggle.

Without conscious forethought, the human mind has tended, and it still tends to convert all possible institutions, events, and human relations into sources of distinctive psychical goods; these in their various types it has craved even as it has craved stimulant or sedative substances which give, temporarily at least, the feeling of strength and freedom from fears and inhibitions. But as the use of the latter exacts a price, often far exceeding the value of the subjective temporary benefits derived from them, so, also, the use of distinctive psychical goods is essentially unhealthful; as stated it brings suffering to many and a reaction often sets in against those who display their real or assumed superiority. These distinctions are employed as instruments in the strife which is constantly being waged for positions of mental-social superiority over others and in which a lowering and defeat of one means a victory and elevation for

the other. As secondary motives, this struggle has been introduced into all human activities, not only into business, but also into science, literature, art, and all other types of creative work. These accessory, subjective motives often exceed in strength the primary, essential and objective motives, those founded in the work itself, and rooted primarily in the struggle with the difficulties encountered in nature and they may greatly interfere with the satisfactions caused by real accomplishment. It is true that such motives, derived from the sphere of the social struggle, may also function as additional incentives to work, but they are essentially the source of the worries so often associated with work and thus they tend to cause depression and exhaustion, when even strenuous work as such would give satisfaction.

However, in different individuals the personality level desired and claimed varies very much, and accordingly also the nature and quantity of distinctive psychical goods claimed by them as their due vary, depending largely upon their upbringing and especially upon the suggestions they received in their early years of life.

In former times it was especially the feudal aristocracy whose right to a high personality level was recognized as valid. This is well and relatively harmlessly exemplified by the Duke of Somerset turning in anger to his second wife, who had tapped him playfully with her fan, and exclaiming, "My first wife was a Percy and she never dared to take such a liberty."* To some extent such claims of the feudal aristocracy and their descendents are still potent today even in democratic countries, and in general, the criteria used in the distribution of distinctive psychical goods, in many respects are still derived from feudal times. But apart from this, every individual has built up a certain personality level, which is determined by his individual experiences, by his sensitiveness or expansiveness, and, also, by the grade which society concedes to him, according to his inherited or acquired social caste. This personality level, characteristic of each individual, greatly influences his attitudes and activities, into which his desire for distinctive psychical goods enters to a larger or minor degree. Likewise, the technique used by different persons in their attempt to maintain their own level or to reach a higher one varies greatly. Some rely almost solely upon their work and upon their helpfulness to others; some apply a social technique, which is well recognized by many, and which was succinctly stated by Lady Mary Wortley Montague with the words "Caress the favorites, avoid the unfortunates, and trust nobody."* These latter persons may be inclined or ready, if necessary, to trade their thoughts, convictions, also truth and justice, as well as simple psychical goods and, even, their friends, for distinctive psychical and material goods which they greatly need in their desire for social advancement and power. In many others these two modes of social reaction are combined in various proportions.

If we now turn from the individual life to the actions and policies of larger groups, such as nations, in principle the same factors are active here as in the former, although with some modifications, which are due to the importance of mass suggestion in the life of groups and in the relative preponderance of the economic, material interests which are shared and understood by the large majority of the members of a group, in contrast to the psychical factors or motives which are of a more individualized nature and concerning which there might be a lack of agreement. However, there can be little doubt that also in international relations psychical factors play a significant role. The traditions of the

* Cited by Louis Kronenberger in "Kings and Desperate Men."

people, the ambitions of some of the leading personalities, the suggestions, systems of thought and ideals potent in them have a large share in shaping national policies. Expressed differently, the need of simple psychical goods, the craving for individual, group or class distinctive psychical goods, and the nature of the inner psychical goods possessed by the dominating personalities also greatly influence national and international group relations.

While economic needs and interests are the primary factors in determining satisfaction and dissatisfaction with general conditions and in sensitizing people in such a way that they are ready for changes in policies, still the mode in which these attitudes find expression in actual life depends largely upon various psychical factors, and there is very little doubt that in the grave condition in which all the nations are today, these factors, elevations of the personality on the one hand and humiliations on the other have played an important part. In the end the significance of all the elements in our culture depends upon their content of psychical goods and on the contribution these elements make to our store of material, simple, distinctive and inner psychical goods and to their availability to individuals. Moreover, in the life of the individual and in the life of larger national and international groups, the total sum of energy used up in social friction caused by the competitive struggle for distinctive psychical goods is very great; this is a total economic loss and entails much waste of human happiness.

If we now return to the question which we raised as to the cause of social discontent, omitting the problems of adjustment in the production and distribution of material goods, which is the field of the economist, this is due at least in part to unsatisfied needs for psychical goods, and the latter again are at least partially caused by the planless manner in which developments have taken place in the sphere of psychical goods in the past; as a result there have arisen abnormal and unhealthy valuations of different types of psychical goods and in particular an overvaluation of distinctive goods in various spheres of social life. These difficulties have been aggravated by the technical advances made in recent times, which tend to cause a still greater depression of the value attached to the individual and to simple satisfactions in social intercourse. In addition, the increase in individual liberty and initiative which democracy provides may have accentuated the evils of an excessive and sometimes ruthless competitive spirit in the field of distinctive psychical goods, which is contrary to the spirit of democracy and which in the end would destroy it. But these unfavorable results of the advances in the physical sciences and in the development of democracy are not inherent in science and in this mode of social organization; they can be separated from the latter and there is hope that they can be avoided. Besides the greatest possible security in the field of material goods there is needed the maintenance of individual liberty and initiative in our social relations as much as this is compatible with the equal needs of others. This implies as much as possible the avoidance of the injurious effects of inhibition and frustration in the functioning of our organism. But there is needed also for the healthy state of mind and body, the cultivation of friendly relations with our neighbors as well as with those farther distant. This requires the extension and intensification of our imaginative power, which enables us to see ourselves in all the others and all the others in ourselves. It also requires a planful limitation of the value attached to distinctive psychical goods and to their application in social life as well as a higher evaluation of the simple psychical goods. It requires the recog-

nition of the dignity of the individual as the level of personality which is needed by every human being and which democracy will give to him. Important as the preservation of individual liberty and initiative is for the creation and maintenance of a healthy state in the individual and group life, we must keep in mind that they are not the only simple psychical goods that are needed but that the others must also be cultivated. However, in order to make such principles function in our social life, it is necessary to make their significance conscious in all members of communities and this requires the teaching of these principles and of the elements of social relations and of social technique in general to minds still young and plastic.

It follows furthermore from these considerations that the factors which will make the individual healthy in mind and body and which will insure the greatest possible security for his personality in the social and natural struggle, will ultimately be also the factors which will make possible rational relations between groups within the nations and between the different nations.

These conditions represent the essence of democracy; democracy is the mode of social organization which satisfies best the human needs of health of mind and body. In all other forms of social organization there is inherent the danger of a suppression of personality, of a lowering of individual initiative, also the introduction of differences in personality levels, which are based on artificial, unreal standards and which do not take into account the value and dignity of the individual; thus they tend to cause undesirable social cleavages and disturbances in the healthy social equilibrium. The principles of democracy must be applied in the life of the individual, in the relations between groups within the nation, and they must be extended also to the sphere of international relations. This must be done consciously and planfully in the same way as other principles of public health are applied planfully, instead of being allowed to drift as they have been in the past.

The problems of the creation, distribution and function of psychical goods are, in the end, problems which concern the health of the individual and of the community and they belong therefore to the sphere of interest of medicine and of the physician in the same way in which the creation and distribution of material goods belong to the sphere of interest of the economist. Both the physician and the economist should be the guides whose advice directs the policies of communities within the nation and the policies in international groups. The physician will thus further the appreciation of the dignity of the individual as man's most valuable possession and he will be the guardian of democracy.

This is an important function, especially at the present time when democracy is fighting against a view of human personality and of life in general which tends to destroy all that is actually and potentially good in our civilization, and to replace the values of the free democratic life by brutal methods of suppression of the individual and of human individuality by a group chosen by themselves to be masters over all, contrary to human experience and to the teaching of science. Let us hope that this will be a passing phase in human history and that it will be followed by a time when science will enlarge and deepen our knowledge of the good life, and when man, and above all the physician, will help to translate this knowledge into actual living.

THOMAS JEFFERSON—SCIENTIST

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This year, April 13 (April 2nd old style calendar) marks the two hundredth anniversary of the birth of Thomas Jefferson. Several studies will doubtless appear appraising his political, social, religious, and philosophical ideas. It seems appropriate therefore in this scientific age to call attention to Jefferson's interest in science, and the scientific developments of his time.

Jefferson was the most scientifically minded president this nation has ever known. "Science is my passion, politics, my duty" he wrote to Harry Inness. And to M. Dupont de Nemours, he wrote, "Nature intended me for the tranquil pursuits of science by rendering them my supreme delight." And again to Dr. Benjamin Rush, he declared that nothing but "revolutionary duties would ever have called me away from scientific studies." Had not these "revolutionary duties" driven him into politics Jefferson might well have taken rank as a scientist with Leonardo de Vinci, Francis Bacon, Sir Isaac Newton, and Benjamin Franklin. Even with all the political demands made upon him he still found time to render a distinct service in the fields of the physical sciences, mathematics, geography, botany, paleontology, agriculture, and natural history.

Jefferson's scientific activities fall quite naturally into five chronological periods. The first period ends in 1784 when he was sent abroad; the second relates to his scientific activities while in Europe, 1784–1789; the third period covers the years 1790 to 1801; the fourth period extends through his two presidential terms, 1801 to 1809; and the fifth relates to his years in retirement, from 1809 until his death in 1826.

First Period, 1780–1784

In his *Notes on Virginia,* compiled during the busy years of 1781 and 1782, Jefferson demonstrated a rare gift of scientific inquiry. These *Notes* were prepared hastily to meet a special need. The French government had instructed Marbois, Minister in Philadelphia, to obtain accurate, statistical information concerning the different states. Marbois turned to Jefferson and asked him if he would prepare this information for Virginia. Jefferson was well qualified for this work. He states in his *Autobiography* that he had always made it a practice to keep careful notes on any information of the country "which might be of use to me in any station, public or private, to commit it to writing. These memoranda were on loose papers, bundled up without order. . . ."[1]

Marbois' inquiry caused Jefferson to put his *Notes* into proper order. It was a tremendous task. He had to do all his writing by hand. He took his *Notes* with him when he sailed for Paris in 1784, where he found he could have them printed for one fourth the price asked by the Philadelphia printers. Not satisfied with the results of the French printer, he next submitted them to John Stockdale, an English publisher. After they were printed he sent copies back to some friends in the United States.

These *Notes on Virginia,* according to the late Dr. G. Brown Goode, Assistant Secretary of the Smithsonian Institution, represent

> the first comprehensive treatise upon the topography, natural history, and natural resources of one of the United States, and was the precursor

[1] Lipscomb, Andrew A. *Writings of Thomas Jefferson;* 20 Volumes; 1903–1905. II, Introductory Notes to Jefferson's Notes on Virginia.

of the great library of scientific reports which have since been issued by the States and Federal government. Though hastily prepared to meet a special need, if measured by its influence, it is the most important scientific work as yet published in América.[2]

To Jefferson, the study of natural history had a decidedly practical side. Plants and trees were put here for a purpose. He classified in minute detail the different types of vegetation found in Virginia. He divided the trees, plants, fruits, and all vegetation in four classes: the medicinal, the esculent, the ornamental, and those useful for fabrication. Besides the common names, he gave them botanical names, portraying the true character of a scientific, professional botanist.

His observation upon the climate of the mid-Atlantic region was far in advance of anything that had ever been attempted. The rainfall, temperature, prevailing winds, wind velocity were all treated in detail. The effect of sea breezes on salt making, the prevalence of sunshine, the seasons when frosts occurred and their effects upon plant life, all testify to the meticulous observations made by him.

No other early American has given such an accurate, detailed account of the rivers of Virginia and the upper Ohio Valley, of the mountains of Virginia and the Appalachian ranges. Jefferson detested generalizations. He insisted above all else on exactness; statistics were of value only when they were accurate.

One of Jefferson's most interesting scientific investigations, led him to contradict Buffon, the celebrated French author of *Natural History.* Buffon, it will be recalled, had advanced a theory then current in scientific circles that animals on the North American continent were degenerating in size. And he had gone to considerable length to prove that those animals that had been domesticated in both continents had degenerated in America. He attributed the cause incorrectly, to the theory that the climate over here was colder and more moist than in Europe. Warmth and dryness, he argued, were more favorable to large quadrupeds.

Jefferson mulled over these theories for some time, and finally came to an exactly opposite conclusion. First of all, he knew the animals of North America. Buffon, he insisted, lacked sufficient climatological, geological, or meteorological data to justify his findings. Jefferson then set about collecting data of his own. By personal investigation and wide correspondence he assembled an immense amount of material. He arranged his data in three tables showing the weights of the animals, so as to give a comparative view.

In his first table Jefferson showed that of twenty-six quadrupeds common to both Europe and America, seven were of equal size. The second table showed that eighteen quadrupeds were peculiar to Europe and seventy-four to America, while one of the seventy-four, the tapir weighed more than all the eighteen together. In the third table the conclusion was reached that with equal care and food the domestic animals of America would reach a growth as great as those of the European stock from which they were derived.[3]

Busy as he was with his *Notes on Virginia* and other activities during the years 1781–1782, Jefferson also found time to take on another scientific, technical study. In January, 1782, the Continental Congress turned to the troublesome question of adopting a standardized monetary system. Robert Morris, financial wizard, brought in a table of the different currencies and exchange rates of foreign coins, and urged the adoption of a fixed standard of value and a money unit. It was a terribly complicated system. Congress postponed action on it until 1784. Jefferson was now a member of Congress and chairman of the commit-

[2] Lipscomb, XIX, iv–v.

[3] Lipscomb, II, 66–68.

tee on coinage. He found the Morris plan sound, but "too minute for ordinary use, and too laborious for computation, either by hand or in figures." He pointed out that—

the price of a loaf of bread, 1/26 of a dollar, would be 72 units, a pound of butter, 1/5 of a dollar, 288 units. A horse or bullock, of 80 dollars value would require a notation of six figures, to wit, 115,200; and the public debt, suppose of 80 millions, would require 12 figures, to wit, 115,200,000,000 units. Such a system of money arithmetic would be entirely unmanageable for the common purposes of society.[4]

Jefferson offered a substitute plan. He would make the dollar the unit of payment, and its divisions would be on a decimal ratio. Jefferson distributed printed copies of his plan to members of Congress, pointing out that the ease with which multiplication and division could be made by using the ratio ten, and the decimal. The advantages of his system were obvious. He also proposed the minting of four coins. First, a gold piece equal in value to ten dollars. Second, the dollar unit itself in silver. Third, the tenth of a dollar, of silver. Fourth, the hundredth part of a dollar, of copper. This system of decimal coinage was adopted both by the Continental Congress and later the Federal Congress, and has remained the basic system to this day.

Second Period, 1784–1789
Scientific Activities in Europe

In the summer of 1784 Jefferson sailed for France to assist Franklin in negotiating some treaties of commerce and trade. When Franklin retired from his diplomatic post the following year, Jefferson was named his successor. The years he spent in France 1784 to 1789, were busy years, but in some respects this was the most pleasant period of his official life. He found time to carry on many scientific investigations. The French accepted him from the very first as a scientist.

[4] Rayner, B. L. Sketches of the Life, Writings and Opinions of Thomas Jefferson, 230.

The two scientific projects in which Jefferson was most interested while abroad were agriculture and natural history. Agriculture came first. Shortly after he reached Paris he was informed of his election to membership in the South Carolina Agricultural Society. In his letter of acknowledgment he sent back some seeds of grass (Malta grass) that had been found especially useful in Malta and in southern France. Later, he sent a collection of acorns from the cork oak, and asked his friends to try them in the South Carolina soil. Jefferson was particularly anxious to introduce the olive culture into the southern states. He sent over several varieties of olive trees and the South Carolina Society accepted them with great enthusiasm, but for some reason they never had much success in developing them.

Jefferson was also interested in rice culture. He was anxious to discover the best methods used in cleaning rice. He traveled down through southern France in 1787 and examined every rice cleaning machine he could find. He also inquired about the methods used by the Italians. Still not satisfied he crossed into Italy and traveled through the rice country in order to study first hand the rice hulling and cleaning machines. He was surprised to learn that the Italians were using the same machines that were being used in South Carolina. He thereupon concluded that it must be the superior quality of the grain that gave the Italian rice supremacy over South Carolina rice.

He decided to send some Italian rice to his Charleston friends, but to his surprise, he discovered that the exportation of Italian rice was prohibited. He then resorted to the ingenious scheme of filling his coat pockets full of rice. At his rooming house he wrapped the seeds in two separate packages and sent them in different ships to Charleston. Both packages reached their destination. These precious grains were distributed to the rice planters of Charleston, and within

a few years, says Curtis, they were producing the best rice in the world.[5]

Later Jefferson sent over samples of an improved rice mill, showing the latest advances in setting the rows of teeth for cleaning the grains. When he discovered an improved quality of corn in Italy, he sent some sample grains to his overseer in Virginia with instructions on how to grow it. In Turin he discovered an improved method for training grape vines. At Casino, France, Jefferson saw an improved rice beater, and spent hours examining it in minute detail.

During the years 1787–1788 Jefferson was busy drafting trade treaties, writing philosophical essays and observing the beginnings of the French Revolution. Yet, he found time to design an improved mold board for plows. He sketched a plan according to a mathematical formula, making the mold board as wide as the furrow, and of a length suited to the construction of the plow. The object was to "secure the regular inversion of a certain depth of the surface soil with the least application of force." For his invention Jefferson was awarded a medal by the Royal Agricultural Society of the Seine.

While on a visit to Holland in the spring of 1788, Jefferson was attracted by a number of their new mechanical contrivances. A saw mill run by windpower caught his attention, and he made detailed drawings of the mill and all of its parts. While in Germany he made a detailed drawing of a new bridge over the Rhine, and entered a lengthy description of it in his diary. He observed that it was supported by thirty-nine small boats, and described the way they were maneuvered in order to let vessels pass through.

In May, 1788, Jefferson wrote to James Madison, informing him that he was sending a pedometer, and gave him explicit instructions as to its use. It was to be carried in the watch pocket of the vest, and attached by tape to the knee band of the breeches. It must have been an exceedingly delicate instrument, since Jefferson cautioned Madison to never turn the hands backward. He should always note where the hands stood when he began to walk, and determine the number of steps by subtracting that number from the number recorded later.[6]

Jefferson was also interested in the new development of steam power, and kept his American friends informed of the advances that were being made in Europe. On October 2, 1785, he wrote Madison describing a steam engine he had seen in Paris used for raising water for fire protection. The following April he was in London, and after studying the application of steam power used for operating a grist mill, he wrote to his friend Charles Thompson describing it in detail. He foresaw the day when this new source of water would be widely acclaimed in America.[7]

The new advances in printing had a special interest for Jefferson. Perhaps because he did so much writing in long hand he welcomed any short cuts that might be invented. In a letter to Mr. Carmichael, December 26, 1786, he told him he was sending him a portable copying press, model of one that he had recently designed. This polygraph, as he called it, was an ingenious double writing desk with duplicate tables, pens, and inkstands. The pens were connected together by a system of parallelograms, with two fixed centers, so that the pens were always parallel. Whatever movement was impressed on one who was simultaneously communicated by the connecting link to the other pen. By this polygraph the copy was made on another paper identical with the original.[8]

During his entire stay in France Jefferson was diligent in studying all the

[5] Curtis, William Eleroy, The True Thomas Jefferson, Philadelphia (1901) 365.

[6] Lipscomb, VI, 460.

[7] *Ibid.*, V, 295–296.

[8] *Ibid.*, VI, 31.

recent advances in the arts and sciences. In his letters to President Stiles of William and Mary; to the president of Harvard; to Charles Thompson; to David Rittenhouse and others he gave detailed reports of the many inventions he had seen. The advances made by the French in science, painting, and music, he declared were the only things for which he envied the people of that nation. In writing to Peter Carr in 1785, he declared, "The acquisition of science is a pleasing employment. I can assure you that the possession of it is, what (next to an honest heart) will above all things render you dear to your friends, and give you fame and promotion in your own country."[9]

Two other sciences to which Jefferson gave considerable attention while in Europe were chemistry and astronomy. He was offended when he learned that Buffon, his natural antagonist had made a disparaging remark about chemistry, describing it as nothing more than cookery, and placed the laboratory worker on a footing with that of the kitchen. Jefferson on the other hand, looked upon chemistry as the most useful of all sciences, and one that would open unlimited opportunities for the human race.

Jefferson had a genuine interest in music, both as an artist and a scientist, and while in Europe he found time to keep up his musical interests. In a letter to Mr. Hopkinson, January 3, 1786, he described a new metronome recently invented by Monsieur Renaudin of Paris. Jefferson had recently examined this instrument, and offered suggestions for making some improvements on it.

> It will be the greatest present which has been made to the musical world this century, not excepting the piano-forte. Its tone approaches that given by the finger as nearly only as the harpsicord does that of the harp. It will be very valuable.[10]

Jefferson sailed for home late in 1789.

[9] Washington, H. A. Writings of Thomas Jefferson, 9 volumes, (1859). Vol. I, 395.
[10] Lipscomb, VI, 22.

Third Period, 1790–1801
As Secretary of State and Vice President

While Jefferson was still in France, President Washington invited him to take over the office as Secretary of State. Jefferson accepted and sailed for America. Busy as he was with the duties of that new office, he found time to continue his scientific interests. One of his first official tasks was to prepare an exact, workable system of weights and measures. He had already given this subject considerable study, but he now desired the opinion of several of his European friends, on this matter. He made a careful study of the system of weights and measures recently introduced in the National Assembly in France. He asked a friend in London to send him a packet of newspapers containing an account of the plan recently submitted by Sir John Riggs Miller to Parliament on this subject. Miller had proposed that a pendulum, 39.107 inches in length be adopted as the standard of measure. The French had also suggested the pendulum as a standard of measure—but recommended it should be 39.181 inches in length. Jefferson took an average of the two, 39.149 inches, and after comparing his results with Sir Isaac Newton's estimate of 39.144 inches, he made his proposal to the House of Representatives in 1790. This document is a classic in scientific literature. But Jefferson was ahead of his time. It was left to another early scientifically minded statesman, John Quincy Adams, to finally secure the adoption of laws regulating the standard of weights and measures in 1838.

Jefferson's most important service to science during his term as secretary of state was the work he did in administering the nation's first patent law. The patent act of 1790 was short, simple and easy to follow. Anything could be patented if it could be classified as "any useful art, manufacture, engine, or device, or any improvement thereon not

before known." It was fortunate that Jefferson, as secretary of state, was charged with the responsibility of administering this law. He was the best qualified person in the nation for this position. Projects of a technical, scientific nature appealed to him. He was constantly encouraging the introduction of new devices and the application of science to every-day living.

The patent law under Jefferson's administration began to function immediately. Within two months after the act had been signed Jefferson wrote that the granting of patents for new discoveries had stimulated inventions "beyond my conception." Jefferson insisted on examining personally every application that was filed. While some of these proved to be useless, "indeed trifling," as he said, yet there were many of such consequence that they would produce great results.

While serving as secretary of state, Jefferson was appointed chairman of a committee in 1792 by the American Philosophical Society to collect information relating to the ravages of the Hessian fly. This insect was threatening to destroy the wheat crop and other grain crops of the country. Jefferson's work in assembling all available data on this pest was the first organized effort in economic entomology in the United States.

In December, 1793, Jefferson resigned as secretary of state and returned to his home at Monticello. During the next three years he devoted considerable time to agriculture. His experiments in crop rotation, which required a six year cycle for completion, attracted considerable attention. He also carried on experiments with an improved plow. Writing to John Taylor of Caroline, December 29, 1794, he declared that "a good instrument of this kind (referring to his plow) is almost the greatest desideratum in husbandry."[11]

[11] Lipscomb, XVIII, 199–200.

During these same years he was experimenting with a drill, called "the Carolina Drill" which was operated for only one row at a time. He wrote to President Washington, June 19, 1796, saying that he was trying to improve the drill so as to make it sow four rows of wheat or peas at 12 inches distances. And in the same letter he described a Scotch threshing machine which he had nearly finished. He had worked from a model which Mr. Pinckney had sent him. He had succeeded in putting the whole works, except the Horne wheel, into a single frame, so that it could be moved from one field to another on two axles of a wagon.[12]

In 1796 Jefferson was elected vice president of the United States. When he left Monticello to go to Philadelphia for the inauguration, he carried with him an extensive collection of newly discovered bones, and an elaborate set of notes describing the studies he had made of them. What a spectacle! A statesman renowned in two continents, elected to the second highest office in the land, entering the nation's temporary capitol, bearing a collection of bones that would claim almost as much attention as any of the affairs of state! The week following his inauguration as vice president, Jefferson read a paper before the American Philosophical Society entitled, "Memoirs on the Discovery of a Quadruped in the Western Parts of Virginia." He called the animal, bones of which he had recently discovered, *The Meglonyx Jeffersoni.* The science of paleontology had its beginnings, as nearly as any science can have a beginning, with Jefferson's paper on *Meglonyx Jeffersoni.* He was immediately elected president of the Philosophical Society and served until old age compelled him to resign in 1814.

Jefferson was an ardent believer in developing the scientific possibilities of

[12] Randolph. Writings of Thomas Jefferson, III, 338.

this young nation. In a letter to Elbridge Gerry in 1799, he wrote:

I am for encouraging the progress of science in all its branches; and not for raising a hue and cry against the sacred name of philosophy; for awing the human mind by stories of raw head and bloody bones to a distrust of its own vision, and to repose implicitly on that of others; to go backward instead of forward, to look for improvement; to believe that government, religion, morality, and every other science were in the highest perfection in the ages of darkest ignorance and that nothing can ever be devised more perfect than what was established by our forefathers.[13]

The sciences which he believed most useful and practicable were botany, chemistry, zoology, anatomy, surgery, medicine, natural philosophy, agriculture, mathematics, astronomy, geography, politics, commerce, history, ethics, law, and the fine arts.

Fourth Period, 1801–1809
President of the United States

During the exciting weeks in February 1801, while Congress was busy trying to break the tie vote between Jefferson and Burr, Jefferson was engaged in correspondence with Dr. Caspar Wistar discoursing on some bones of a mammoth that had recently been dug up in Ulster County, New York. Pressing as were the matters of state they did not claim his undivided attention.

Within less than three weeks after he had been inaugurated president, Jefferson was writing to Moses Robinson, United States Senator from Vermont, expressing the hope that the people of America, in all professions, would see the necessity for scientific advancement. He pleaded for an open minded attitude in all scientific matters. He was especially anxious to have the members of the clergy recognize the advances in sciences.

I am in hopes their good cause will dictate to them, (the clergy) that since the mountain will not come to them, they had better go to the mountain; that they will find their interest in acquiescing in the liberty and science of their country, and that the Christian religion, when divested of the rags in which they have enveloped it, and brought to the original purity and simplicity of its benevolent institutor, is a religion of all others most friendly to liberty, science, and the freest expansion of the human mind.[14]

During his eight years as president, Jefferson continued to give such time as he could spare to matters of scientific interest. But matters of state did not permit as much study or correspondence as in former years. The most dramatic scientific event of his first term, carried over into his second, was of course, his decision to send Lewis and Clark on that scientific expedition into the far northwest.

From 1801 to 1807, aside from the Lewis and Clark expedition, only a few letters can be found bearing specifically upon scientific subjects. But as he approached the end of his second term an increased interest is noted. On January 3, 1808, he wrote to Robert Livingston in Paris, thanking him for sending over the copies of the *Agricultural Proceedings*. He expressed surprise to learn that the system of crop rotation was just coming into common use in France.[15]

To John Taylor of Caroline, January 6, 1808, he described an improved grain drill that he had especially made for his fields. He planned to send one over to the Agricultural Society of Paris. He had recently received an improved plow from the Paris Society, which according to the French inventor claimed to be the best plow ever built—one that required only two thirds the force ordinarily used to pull other plows.[16]

Jefferson was eagerly looking forward to his retirement. In a letter dated July 15, 1808, to Monsieur Lasteyrie, he said:

When retired to rural occupation, as I shall be ere long, I shall devote myself to occupations

[13] Ford, P. L. Writings of Jefferson, VII, 328.

[14] Randolph, III, 471.

[15] Lipscomb, XI, 411.

[16] *Ibid.*, XI, 414.

much more congenial with my inclinations that those to which I have been called by the character of the times into which my lot was cast. . . . What remains to me of physical activity will chiefly be employed in the amusements of agriculture.[17]

It was with genuine relief that on March 4, 1809, Jefferson retired from "the dry and dreary waste of politics."

Fifth Period, 1809–1826
In Retirement—The Sage of Monticello

Jefferson retired from "the dry and dreary waste of politics" March 4, 1809, and returned to that place which he loved "more than all the kingdoms of earth." The "Sage of Monticello" would have preferred to become the "Hermit of Monticello," but his fame as statesman, diplomat, and scientist, would not permit. During his first year in retirement he spent considerable time constructing a plow, fitted out with his special mold board, for the Agricultural Society of the Seine. He believed less power would be required to pull his plow than the plow which the Society had sent him. But in this, as in all of his other scientific theories, he wrote Robert Fulton, "it is the actual experiment alone which can decide."[18]

In April, 1913, he wrote Charles W. Peale, prescribing a scientific method of plowing hilly ground, known today as contour plowing. The furrows, he said, should be plowed along the side of the hill, horizontally and in parallel lines. This could be accomplished by means of a triangular level, whereby points for guide furrows were marked out on the hillside, at distances of about thirty to forty yards apart. From these guide furrows the intervening furrows could be determined.[19] This plan was apparently Jefferson's own, and again it reveals his extreme meticulousness in planning his scientific projects—in this case, even to the uniformity of distances between furrows on the hillsides of his farm.

During his years in retirement Jefferson was busy with many other inventions. He designed an improved hemp break, which powered by a single horse would do "the breaking and beating of ten men," a new threshing machine, an adjustable book case, a whirling chair (the modern swivel chair), a folding chair, a carding machine, and a lock dock for laying up vessels.

Jefferson was a strong advocate of applied science. In March, 1818, he wrote to Benjamin Waterhouse, declaring:

When I contemplate the immense advances in science and discoveries in the arts which have been made within the period of my life, I look forward with confidence to equal advances by the present generation, and have no doubt they will consequently be as much wiser than we have been as we than our fathers were, and they than the burners of witches.[20]

In some respects Jefferson belonged to the twentieth century rather than the late eighteenth or early nineteenth. He had very definite views on the relations between science and government. As he looked back over a half century of active participation in political life, he wrote in 1821 that:

Science is more important in a Republic than in any other government. And in an infant country like ours, we must much depend for improvement on the science of other countries, longer established, possessing better means, and more advanced than we are. To prohibit us from the benefit of foreign light, is to consign us to long darkness. . . . Science is important to the preservation of our Republican government and it is also essential to its protection against foreign powers.[21]

Jefferson died on July 4, 1826. Thus ended the career of our first statesman-scientist. His scientific interests comprised an important part of his whole thought and definitely shaped his entire philosophy of life.

[17] *Ibid.*, 92.
[18] Lipscomb, XIX, 173.
[19] Lipscomb, XVIII, 279.
[20] Lipscomb, XV, 87, 165–166.
[21] Washington, ed. VII, 221.

DID THE FOLSOM BISON SURVIVE IN CANADA?

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I

In 1927 a wave of incredulous surprise swept the archeological world. The discovery, at Folsom, New Mexico, of the bones of a supposedly extinct Ice Age bison in association with implements of human manufacture, shook to its foundations the theory of conservative archeologists that man had been a late arrival in America. Instead, a series of discoveries scattered over the High Plains region of the United States has revealed that man reached the American continent in time to see the last of the giant mammals of the Ice Age—the mammoth, the huge and lumbering sloths and the now extinct American horses and camels. All this is now archeological history. The specialist no longer scoffs as the earth continues to yield up evidence of these thinly scattered mammoth hunters remotely ancestral to the American Indians of to-day. The sole question not entirely answered to the archeologist's satisfaction, as yet, is the exact date at which the last of these extinct animals disappeared. And since these early people hunted the huge buffalo of the time with marked success, particular interest has lingered about these long-horned relatives of our familiar American bison of to-day.

The American bisons of the late Ice Age are known primarily from skulls and various fragments of the body skeleton recovered over a wide range of territory in the United States. That they averaged somewhat larger in size than the existing buffalo is well known. Differences in horn and skull structure among different types have resulted in at least the tentative setting up of several distinct species, some of which were apparently in existence at the same time. Some of these types undoubtedly constitute valid species. In the case of others, however, different observers may have been too liberal in the description of new species on the basis of inadequate material which, at best, may have represented only local varieties or races. It is possible also that certain of these co-existing types may have mixed or interbred, thus increasing the problem of systematic assignment. Furthermore, sex differences may have played a part in confusing the paleontologist. No really authoritative and complete study of these bison, in spite of their growing importance to the archeologist, has been made in recent years.

The common tendency of late has been to term most of the bison recovered with Folsom or Yuma archeological remains as *Bison taylori*. As so used, however, it must be remembered that the appellation *taylori* probably includes animals which some years before the Folsom controversy would have been termed *Bison antiquus* or *Bison occidentalis*. *Bison taylori* was described by Hay and Cook from the original Folsom quarry at Folsom, New Mexico. There is no doubt that it was somewhat larger and more powerfully horned than the existing American bison. It was, however, closely related to the latter form which succeeds it at some undetermined point within either very late glacial or early Recent time. In other words, at a point in years anywhere from perhaps 15,000 to 8,000 years ago.

It is quite likely that these big animals were adjusted to cooler Ice Age conditions and failed to hold their range with the onset of postglacial warmth and drouth. The existing bison may have been a successful southern variant of this stock. Adjusted to enduring a dryer and hotter prairie environment, it may have flooded in over the range once held by the larger and more formidable species.

Bison taylori in this case may have survived longer toward the north where he could have intruded into areas once covered by the great ice-sheets. Because of inadequate investigation of the vast Canadian wilderness, our information here is almost entirely speculative at present. The story which we have presented so far is one whose essential outlines are accepted by all archeologists at least in so far as it concerns discoveries within the United States. It is within this northward area, then, that a certain degree of mystery presents itself—a mystery which has seemingly escaped the eye of those very students who have been struck by man's association with an extinct ice-age animal in the High Plains region of the United States.

II

When the first voyageurs explored the wilderness of the Canadian Northwest they found bison ranging over most of the upper part of the Mackenzie Basin. As time passed and the acquaintance of the white man with the North American game animals increased, many hunters began to express the view that the northern Canadian bison were somewhat distinct in size, pelage and habits from their relatives, the Plains bison. On the whole they were regarded as a larger and more rugged variety of the southern form. An early quotation from Sir John Richardson (Fauna Boreali-Americana 1829) will illustrate the trend in the literature:

> The bison which frequent the woody parts of the country [near Great Slave Lake] form smaller herds than those which roam over the plains, but are said to be individually of greater size.

Finally, in 1897, the paleontologist, S. N. Rhoads, clearly defined the wood bison as a subspecies (*Bison bison athabascae*) of the better known Plains bison (*Bison bison*), and supplied its scientific description.[1] Since that time there has been little attempt to challenge the form as a valid variety of *Bison bison.*

Some of the early descriptions of these big animals, though lacking metrical expression, are not without interest and may well serve to introduce the features which will later demand our attention with reference to the paleontological past. Though variations and misstatements exist in the descriptions, there is considerable emphasis, particularly in the earlier accounts, upon large size and greater length of horn "nearly twice the length of the plains' ones and much straighter."[2]

The naturalist, Ernest Thompson Seton, in 1914, describing a large bull which he was able to examine in Canada, speaks of the "immense horns long and curved," of the "enormous bulk, evidently larger than any Plains buffalo and much like an aurochs."[3]

When Rhoads in 1897 gave his description of the type, he pointed out that "In athabascae the relative length of the horns and horncores to the size of the skull is about the same or even greater than in antiquus. . . ." Though endeavoring to establish distinctions,

[1] S. N. Rhoads, "Notes on Living and Extinct Species of North American Bovidae," *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. 49, pp. 492–500, 1897.

[2] *Ibid.*, p. 497, quoting H. I. Moberly. Also see C. Gordon Hewitt, "The Conservation of the Wild-Life of Canada," p. 124. Scribners, New York, 1921.

[3] E. T. Seton, "Lives of Game Animals." Doubleday Doran, N. Y. 1929. Vol. III, Pt. 2, p. 707.

Rhoads concludes that "the weight of evidence favors their position between *B. bison* and the most recent fossil species."[4] *Bison antiquus,* of course, is one of those types of late Pleistocene bison suspected of association with early man in America. In fact, in the eyes of some paleontologists, *Bison taylori,* the bison found at Folsom, New Mexico, is really only a varietal form of *antiquus.*[5]

In spite of these tantalizing statements, which could easily be multiplied by scanning the literature, a marked confusion seems destined at the present time to obscure forever the true affinities of the northern bison. The tragedy happened in the following manner: The northern bison, just as in the case of their Plains' relatives, became steadily reduced in numbers throughout the nineteenth century. At one time in the eighteen eighties or nineties, they were definitely threatened with complete extinction. Just how close they came to disappearance is not known,[6] though estimates have ranged as low as fifty head.[7] In 1893 the first laws were passed to protect the animals and, though inadequately enforced, they served to relieve the situation. A small upswing in numbers took place during the following years.

In 1925, however, the Canadian government carried out a policy which, though well intentioned in terms of game conservation, has served to make a complete investigation of the original character of *B. bison athabascae* exceedingly difficult. Large shipments of Plains bison were introduced into Wood Buffalo Park, a tract of land in Northern Alberta roamed over by the last of the northern bison.[8] Hence, at the present time, the two varieties are inextricably intermingled. One of the tragedies of this situation lies in the fact that save for a few measurements on the type skull as given by Rhoads, no authentic measurements exist in print. It is true that a few measurements have been given of skulls collected since the introduction of the Plains bison into the Wood Buffalo preserve, but it is obvious in these instances that the strain represented is uncertain.[9] Moreover, they were collected before the archeological and paleontological problem which we are approaching had become significant enough to center attention upon what was needed in the way of information.

III

Now what has this remote bison remnant to do with the archeological past in which we are interested? Primarily this. In the first place, no attention has been given in archeological or paleontological literature to the position and range of this variety of bison during the maximum southward stand of the Wisconsin ice which represents the last glacial advance of the closing Pleistocene or Ice Age. If *Bison bison athabascae* existed during this period its range may well have projected downward into the

[4] Rhoads, *op. cit.*, p. 500.

[5] E. H. Barbour and C. Bertrand Schultz, "Paleontologic and Geologic Consideration of Early Man In Nebraska," *Bulletin Nebraska State Museum*, Vol. 1, pp. 434–435, 1926.

[6] H. M. Raup, "Range Conditions In the Wood Buffalo Park of Western Canada with Notes on the History of the Wood Bison," *Special Publication of the American Committee for International Wild-Life Protection*, Vol. 1, No. 2, p. 5, 1933.

[7] J. A. Allen, *Bulletin American Museum of Natural History*, Vol. 13, p. 67, 1900.

[8] A formal protest was made by the American Society of Mammalogists. Prophetically, the protest reads in part as follows: "Interbreeding would take place between the races of Plains Buffalo and Wood Buffalo, so that the distinctive characteristics of the Wood Buffalo would be lost in a few generations, and in this way the largest and noblest game animal of North America would pass out of existence as such." A. B. Howell, *Canadian Field Naturalist*, Vol. 39, p. 118, 1925.

[9] Raup, *op. cit.*, p. 19, 33. Also J. Dewey Soper, *Journal of Mammalogy*, 23: 144, 1942.

United States because its historic range would have been largely ice-covered.

Under these circumstances, there is a very genuine possibility that its bones might appear in the western deposits where the traces of early man in America are now in the process of discovery. Because of its size, irrespective of whether we regard it as directly related to the extinct form *Bison taylori,* limb fragments of this bison might easily be attributed to the extinct form. From this standpoint alone the animal deserves more attention than it has yet received in the literature.

The writer has repeatedly emphasized that where identifiable skull fragments are lacking, as is often the case in cave deposits and sand "blow out" sites in the West, limb or other fragments may be the only means of establishing the presence of bison. If these fragments are associated with Folsom or Yuma points, there has been a strong tendency to assume automatically—particularly if the size of the limb bones is reasonably large—that the bison represented is the same type known from Folsom, New Mexico, or the Lindenmeier site at Fort Collins, Colorado. Now most certainly there is every reason for regarding this as a reasonable assumption. Nevertheless, so long as the skull is missing, *absolute, positive identification is impossible.* The fragments of the body skeleton of the late Pleistocene bison overlap in measurements upon the normal range of *Bison bison,* and do not differ enough morphologically that they can be separated, at least so far as present knowledge goes, on the basis of non-metric characters.

Allen recognized this fact many years ago when he wrote:

> The female of the larger extinct species, judging from the sexual differences seen in the living species, would apparently about equal in size the male of the smaller one, and hence it is difficult to positively, specifically assign such specimens as detached teeth or single bones of the extremities.[10]

Only where sufficient long bones are present to derive data capable of statistical manipulation might something be done on the basis of metrics alone. Yet even here the necessary comparative data have not been adequately compiled. Statistical developments in paleontology with the notable exception of the work of Simpson[11] and a few others have lagged. The zoologist Richards stated no less than the simple truth when he said, "Taxonomic description of species is usually insufficiently quantitative. . . . Even where linear measurements are given they are not usually recorded in a form suitable for analysis. Standard deviations are rarely calculated even where averages are recorded."[12]

In the light of these technical difficulties which we have just reviewed, it would appear that there exists a reasonable possibility that *Bison bison athabascae* represented, at least in a mixed form, the last of that Ice Age bison which early man had hunted in the western plains. If that bison as represented by the form or varieties variously designated as *taylori, antiquus* or *occidentalis* was adjusted to cooler and more forested conditions, it may, under the rising temperature following the ice-retreat, have moved along the fringe of the receding ice toward the north. At the same time its near relative or actual mutant, the existing Plains bison, may have infiltrated into its former range. This latter animal, doubtless better adjusted to postglacial warmth and dry

[10] J. A. Allen, "The American Bisons: Living and Extinct," *Memoirs of the Museum of Comparative Zoology,* Harvard University, Cambridge, Mass., p. v, 1876.

[11] G. G. Simpson, *American Journal of Science,* 239: 785–804, 1941.

[12] O. W. Richards, "The Formation of Species," in G. R. de Beer, "Evolution: Essays on Aspects of Evolutionary Biology," Oxford Press, 1938, p. 96.

prarie conditions, continued to flourish into historic time. The big Woodland bison, perhaps originally representing the *taylori* type, mixed and intergraded somewhat with the Plains bison in the northern areas. It suffered a brief period of isolation when the southern bison were exterminated and then, due to the renewed introduction of numbers of Plains bison, was tremendously diluted as a type. This dilution is not likely to have been entirely a product of late mixture, unfortunate though the latter has proved. In the days of the great herds it is not likely that there was a complete dichotomy between two such closely related forms.

The few measurements given by Rhoads of a specimen collected before the 1925 introduction of Plains bison into the preserve, fall within the range of measurements recorded for individual fossil remains of specimens of *taylori* and *occidentalis* here in the United States. Unfortunately no extended series of measurements of early specimens exist, and no early skulls are figured. Most of the few records available are of the living body and are not directly comparable to the osteological measurements of the paleontologist. Mystery clothes both the disappearance of the big bison hunted by Folsom Man and the shadowy northern form whose description, at least in some instances, sounds suspiciously similar. Because of the undoubted intermingling, however, both early and late, the situation is not one which promises easy clarification.

Nor must the thesis of this paper be taken opportunely as justification for dismissing the antiquity of the Folsom and related cultures. Folsom Man knew other extinct Pleistocene beasts besides *Bison taylori*. In addition, even if we had final and decisive proof of the relationship of *taylori* to *Bison bison athabascae*, or could show the actual survival of the former in the northern woodland within recent centuries, we would not have altered the possible antiquity of Folsom Man. Rather, by relating the shifting bison ranges to the glacial events of the terminal Pleistocene we may profitably consider whether so marked a modification of the type of bison within the High Plains area of the United States can be reasonably divorced from a direct relationship to the climatic changes of that period. It is by no means without interest that the only documented discovery of both *Bison bison* and *Bison occidentalis* in a deposit which may represent the contemporaneous existence of both forms is from a peat bog in Minnesota surmounting Wisconsin drift.[13] Here, perhaps, is the big glacial form fading northward and here is *Bison bison* coming in. Interestingly enough, one or two of what seem to be the most recent survivals of the late Pleistocene bison have been reported from Canadian areas.[14]

Only more extended exploration of the Canadian wilderness and the intensive comparison of its fossil bisons will illuminate the whole problem. Until that time, however, a question must exist as to whether the "extinct" Folsom bison lingered on into historic time, at least as an attenuated and mixed remnant on the northern fringe of that great continental bison range which the early travelers described as "making the earth one robe."

[13] Frank Leverett, "Quaternary Geology of Minnesota and Parts of Adjacent States," *U.S.G.S. Professional Paper* No. 161, p. 144, Washington, 1932.

[14] O. P. Hay, "The Pleistocene of the Middle Region of North America and Its Vertebrated Animals," *Carnegie Publication* No. 322A, Washington, 1924, p. 200.

BOOKS ON SCIENCE FOR LAYMEN

MAN'S POOR RELATIONS[1]

MAN's "poor relataions" are the apes, monkeys and lemurs which, together with man, constitute the mammalian order of Primates. The technical literature appertaining to primates has grown to respectable size especially during the last few decades (see T. C. Ruch, Bibliographia Primatologica, 1941), but no one up to now had ventured to make use of this literature for producing a book in English which brings together in a single volume all the available information on man's nearest animal relations. We do possess comprehensive technical monographs on the taxonomy of primates (notably D. G. Elliot, Review of the Primates, 3 vols., 1913), on the general natural history and psychology of the man-like apes (especially R. M. Yerkes and A. W. Yerkes, The Great Apes, 1929), on the brain of primates (*e.g.*, F. Tilney, The Brain from Ape to Man, 2 vols., 1928), and many other splendid works, but these are always limited in scope to one or a few of the many different specialities. In the volume under review the educated layman is finally told, based upon authoritative sources, what his numerous cousins look like, where and how they live, what and how they eat, why and how they fight, how and when they love, how they are constructed, what their ancestors were like, which among the many resemble man most closely, and a great deal more besides. All these varied data are of greatest help for a full understanding of human nature since all primates, including man, are the results of more or less diverging evolutionary experiments derived from one, long ago extinct, ancestral stock which gradually became changed by widely varying degrees into the six hundred odd different species of to-day. That man is merely a modified monkey has come to be fully recognized not only by anatomists and physiologists, but also by psychologists and lately even by some sociologists. The long standing lack of a comprehensive popular book on primatology is a reproach to our scientific age which prides itself on sharing its findings with the general public. The average layman of to-day possesses hardly more interest in or knowledge of his simian cousins than did Gilbert and Sullivan who stated some time ago: "Man, however well behaved, at best is but a monkey shaved."

Professor Hooton says of his present book that it "represents an anthropologist's temporary revulsion from the study of his own kind and his resort to a contemplation of other primates which, if they are monkeys, behave in a manner befitting monkeys, and if they are apes, live up to their apehood. They have probably fulfilled their evolutionary aspirations, if they have any. At least they make no pretense of being better and more intelligent than they are. If man insists upon aping the apes, he ought at any rate, to quit posing as an angel." In his introduction the author remarks that: "When you have considered this very general and non-technical summary of man's physical uniqueness, you are likely to conclude that he is just another primate after all and not so godlike in his aberrances as we commonly fancy him to be." It is evident that the author, as all competent students of primates, takes no undue pride in man's achievements, whether of the body or in behavior, and that he is not the least ashamed of his animal kinsfolk.

The first part of the book, and really more than one third of it, is devoted to what are called the "Ape Aristocrats," *i.e.*, that small and select company of man-like apes, the African gorilla and

[1] *Man's Poor Relations.* Earnest Hooton. Illustrated. xl + 412 pp. $5.00. 1942. Doubleday, Doran and Company.

chimpanzee and the Asiatic orang-utan, siamang and gibbon. These resemble man unquestionably most closely in body and mind and, indeed, are in some respects even more highly developed than is man himself. It is not for this reason alone, however, that so much space has been assigned to these five genera, but it is due also to the fact that as much has been learned concerning these few anthropoid apes as about the remaining fifty odd primate genera together. The second and third parts of the book describe the numerous Old and New World monkeys in considerable detail. This is followed by a section dealing with the lowly prosimians and their varied and localized specializations. The final part of the volume, entitled "Man and His Primate Peers and Inferiors," summarizes the most significant discussions of the preceding chapters and this under the following main headings: Sex and Society; Blood and Relationship; Brains and Behavior; Bones and Body Build; Extinct Ancestors and Collaterals—Mostly Teeth; and finally Evolutionary Prospects.

As an introduction to primatology and as a first attempt to produce a popular and comprehensive textbook on non-human primates this volume is a welcome addition to the libraries of anthropologists and psychologists; indeed, it is to be hoped that it will find a place on the bookshelves of all people aspiring to a real "liberal education." It is very entertainingly written and illustrated generously with excellent and well-selected photographs. That it contains some minor errors and inaccuracies is hardly surprising in a work of this vast scope including many widely differing and often highly specialized fields in each of which only an expert can know all that has become known and discriminate between tentative and well-substantiated results. The comparatively brief references to the anatomy of the soft parts in the various groups of primates are far from doing justice to the present state of our knowledge concerning these complex problems. In this field considerable progress has been made in recent years, particularly through the work of American investigators, notably Wislocki, Fulton, Straus, and others.

Professor Hooton's latest book fills a great need by stimulating popular interest in primatology and by counteracting the anthropocentricity which is so difficult to eradicate in our thinking. People should become better acquainted with Man's Poor Relations and this can be easily and pleasantly accomplished by reading this frank account of all the other members in man's zoological fraternity—the Primates. It is most approprite that the volume has been dedicated to Professor Robert M. Yerkes, who, more than anyone else, has enriched our knowledge of the behavior of the man-like apes.

ADOLPH H. SCHULTZ

CUCKOOS AND THEIR EGGS[1]

THIS book, based on the author's very large collection of parasitic cuckoos' eggs, mostly from India and Europe, and his long interest in the study of these birds, deals mainly with the problem of the evolution of adaptive similarity between the eggs of the parasites and those of their hosts. Unfortunately the bulk of the material was collected by untrained and even native assistants, with the result that the data are often open to suspicion, while to make the matter still less satisfactory the author seems to feel that his belief in his conclusions can be transmitted to his readers without adequate supporting evidence. This makes the book very disappointing indeed as a result of a lifetime of effort. However, there are some data and some ideas contained in it that are of interest, but it takes a special student of the sub-

[1] *Cuckoo Problems.* E. C. Stuart Baker. Illustrated. xvi + 207 pp. 25/–. 1942. H. F. & G. Witherby, Ltd. (London).

ject to pick out the kernels of grain from the chaff. For the general reader this critical selection is well-nigh impossible, and the only benefit that he may hope to derive from the book is a general picture of what the parasitic habit of the cuckoos is like without getting any satisfying explanation or even clarifying approach to it. On the other hand, it must be said in the author's defense that as experienced a student of adaptation as Poulton (who contributes an appreciative foreword to the book) appears to consider the work important, interesting and valuable as a contribution to evolutionary studies. All the present reviewer can say is that he does not agree.

To state the author's main problem in a few words, the general picture is this: While the individual species of cuckoos victimize many species of birds, the tendency is for each individual hen cuckoo to use nests of but a single species of fosterer; the eggs laid by any one cuckoo are all very similar, although there may be wide variation in the eggs of each species of cuckoo; in a large number of cases there is a general (and in some cases a close) similarity between the eggs of the parasite and those of its host or fosterer.

Baker's approach to this problem is to assume that those cuckoos that show little or no egg similarity to their hosts are more primitive as parasites than those that show more complete egg adaptive similarity. While it is very easy to arrange the material in this way there is no proof that it is the correct one. Furthermore, Baker assumes that parasitism is not a secondarily arrived at condition in the cuckoos (involving an historical loss of the nest-building and egg-incubating instincts) but an original one, right through from some hypothetical reptilian ancestor (!). Aside from the fact that this is so very unlikely as to be dismissed from serious consideration, it implies a contradiction to his argument for the need of adaptive resemblance in eggs, for the cuckoos that he assumes to be less well developed as parasites have then survived successfully a longer time than those with better developed egg adaptations, and appear to be in no danger of dying out because of their egg "handicaps."

In spite of its very serious shortcomings the book presents some basic data of interest and should be consulted (but with great critical discretion) by a reader intending to study the complex problems involved. The book is compact in its textual matter and quite free from typographical errors and is illustrated by eight colored plates of eggs and four black and white ones of birds and nests. There is no index.

HERBERT FRIEDMANN

INTIMATE STUDIES OF INSECTS

"A LOT OF INSECTS"[1] is the wholly inadequate title of the very remarkable new book by Dr. Lutz. Far from being a mere annotated listing of the 1,402 species of insects that he collected on the suburban lot on which he lives with them, it is the repository of the ripe experience of a lifetime devoted to the first-hand study of insects and their ways. The book is a record of personal observations and experiments, which as the brief preface indicates were begun where "the laboratory was sometimes in our cellar, and sometimes in one of the flower beds on the lawn," and were continued wherever the service of the American Museum of Natural History called him.

It is the kind of book that only Dr. Lutz could write. It is the story of his own personal interests in and experiments with insects of many kinds. It is all informing and much of it is very entertaining. Flashes of humor and unexpected turns of thought abound, and much good-natured dealing with controversial questions, and frequent confes-

[1] *A Lot of Insects.* Frank E. Lutz. Illustrated. 304 pp. $3.00. 1941. G. P. Putnam's Sons.

sions of ignorance, that indicate the highest type of wisdom. He says "Let us not be dogmatic about things of which we are really ignorant."

It will do a lot of people a world of good to read this book.

JAMES G. NEEDHAM

KNOW THYSELF[1]

PSYCHOANALYSIS has benefited a great many people who otherwise would have remained crippled and ineffectual in personal and social relations. In view of the great deal of time, money and energy that has to be expended to effect a successful analysis, it appeared to Dr. Horney pertinent to raise the question whether self-analysis was possible. Hardly, however, does she state the question, than immediately comes the answer that such an analysis is at best a matter of considerable doubt; and in this she is entirely right, for the problem is a pseudo-problem. The successful advance of psychoanalysis is perhaps the best argument against self-analysis. The office of the psychoanalyst is filled with patients who have attempted from time to time to effect a cure by self-analysis, not only with negative but often disastrous results, and no patient is more difficult to handle than he or she who has made various attempts at self-analysis. The book, therefore, is devoted to the discussion of the more limited types of self-analysis which are confined to those cases that have at one time or another been or continue to be under the care of the analyst. In this sense, therefore, the title of the book is a misnomer and entirely misleading, for the readers, on the basis of the title of the book, would suppose that the author discusses personal self-analysis without the help of anyone, yet it turns out that the book deals entirely with such types of self-analysis as are only possible under the guidance and the help of the psychoanalyst.

[1] *Self-Analysis.* Karen Horney. 309 pp. $3.00. 1942. W. W. Norton and Company, Inc.

It is not that Dr. Horney herself is unaware of the limitations of self-analysis as given above, for she offers numerous arguments against it, citing, for instance, the case of Rousseau. She could have given a closer instance in this country of Professor William Ellery Leonard, who, in his "The Locomotive God," has made a determined effort to analyze himself. Any one, reading these two books and any others of this type, will have no difficulty seeing that all these strenuous attempts at self-analysis completely fail for the very reason that in such analysis the patient works against his own inner resistances which he is too blind to perceive and, therefore, can not dispose of. It is in order to combat the development of resistance that competent analysts the world over invariably require the patient to dismiss psychoanalysis from his mind except during the actual analytic session. Additionally, in self-analysis, the subject is unable to establish a transference, the need of which is an acknowledged axiom in analysis and the very essence of a psychotherapeutic cure. But we do not have to cite the examples of Rousseau and Professor Leonard. We have a closer instance at hand in the case of Freud himself, who, as the originator of psychoanalysis, has made an exceptionally strong effort to analyze himself. Any one who is at all acquainted with psychoanalysis knows how many things Freud has missed in his own life because he was unable to overcome his own resistances. The discovery by him of the so-called castration complex is found, on unbiased and objective analysis, to be but a rationalization of his own powerful, but unanalyzed masculinity complex. If Freud himself was unsuccessful in self-analysis, what chance does an ordinary mortal have? Again, recognized psychoanalytic organizations, including the one to which Dr. Horney belongs, demand of prospective analysts that they be first analyzed. If this is demanded of normal

physicians, can less be expected of sick laymen?

Apart from these considerations, however, the book would still have some justification were it not written in a novelesque, popular, but very deceptive style. The material presented is not discussed in anything like a scientific manner. The scientifically oriented reader who would expect the cases to be planned, and precisely and systematically organized, will have great difficulty in reading the book. Cases are presented in small bits with many interruptions. Thus, the most fully described case runs along for close to two hundred pages, a little bit here, a little bit there; these bits of history being sandwiched in between other material not directly related to them. The style is deceptive because it reads very easily, but when one gets through reading, it is exceedingly difficult to get hold of the stuff and substance of the book. It is like a vegetarian dinner, which fills you while you are eating, but half an hour later you are hungry again.

The book should never have been written. It adds nothing to our clinical knowledge as such, and nothing to the otherwise good scientific reputation of Dr. Horney. It certainly will not be appreciated by trained psychoanalysts. The general practitioner, who knows little about it, will fail to understand its meaning and implications. Unfortunately, it is likely to get into the hands of the lay public, to whom the author and the publisher make a most obvious appeal, but where it is likely to do much more harm than good. The general public should have no greater interest in psychoanalysis as a therapeutic and medical procedure than it has in abdominal surgery or ophthalmology. The reviewer fears that Dr. Horney suffers from a "popularity complex" and is overreaching herself in order to reach the public. Let us hope that the book will be the last of its type and will not be followed by such popular expositions as "How to Interpret Your Own Dreams" or "Psychoanalysis by Correspondence."

B. K.

THOMAS JEFFERSON MEMORIAL DEDICATED IN WASHINGTON ON APRIL 13

THE PROGRESS OF SCIENCE

DEDICATION OF THE JEFFERSON MEMORIAL[1]

On April 13, 1943, the two hundredth anniversary of the birth of Thomas Jefferson, the memorial a proud nation has erected in his memory was dedicated. Engraved on its marble walls are a few of his words that express implicitly the Declaration of Independence, the Four Freedoms and the high aspirations of scientists.

I have sworn upon the altar of God hostility against every form of tyranny over the mind of man.

Jefferson is known as the author of the Declaration of Independence, successor to Franklin as United States Minister to France and President of the United States for two terms (1801–1809), but of himself he once wrote, "Nature intended me for the tranquil pursuit of sciences by rendering them my supreme delight." Yet it was his fate to be one of the foremost leaders of the American Revolution, to witness the storming of the Bastile in 1789 as another people plunged into revolution, and to spend forty years of his life in political service of his country during the stormy period when it was evolving into an independent nation.

In spite of his arduous political life, Jefferson always maintained his interests in science. While he was minister to France he was respected and admired in literary and scientific circles as well as by statesmen. In fact, he successfully challenged Buffon's opinion that animals had degenerated in the Western Hemisphere. He sought out and sent to America many kinds of plants and animals that he thought might be useful in the New World. In 1796 he was elected President of the American Philosophical Society, and when he went to Philadelphia the following year to take the oath of office as Vice President of the United States, he took with him a collection of fossil bones of a large mammal and the manuscript of a memoir on them for presentation before the American Philosophical Society. He was President of the Society again during his two terms as President of the United States.

Jefferson's taste found their fullest expression in the building of beautiful Monticello on a high rounded hill overlooking Charlottesville, Virginia, with the lovely Blue Ridge a few miles beyond to the west. He was his own architect for the thirty-five-room mansion to which he took his bride on New Year's day, 1772. The timbers in it were cut in his own forests, the rocks were taken from his hills, the bricks were made from his soil, the nails were fashioned in his shops. He laid out the principal rectangle, the octagonal central hall, the living and dining rooms, the guest chambers, the terraces, the kitchens, the servants' quarters, the stables, the spacious lawns and gardens, and he planted the shrubs and trees. His large clock and weather vane were designed to be equally visible from the interior and the outside, and every room carried the marks of his thoughtful attention. This home and the University of Virgina are expressions of a Jefferson, a very human and noble Jefferson, largely only a name to the present generation, but whose lofty mind and high purposes will become somewhat known by the millions who will visit the marble memorial by the Potomac.

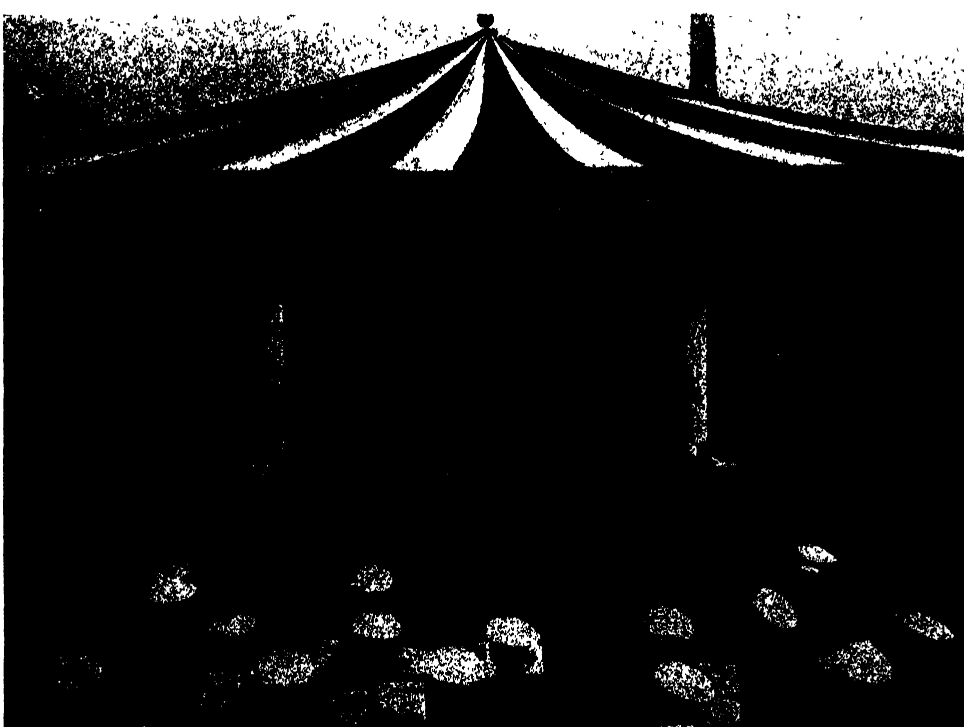
No one can evaluate the innumerable influences, hereditary and environmental, that with infinite interactions determine the qualities of an individual. But Jefferson left words expressing the influence of three of his teachers in the College of William and Mary on his life:

[1] Text by Dr. F. R. Moulton; photographs by Abbie Rowe, printed through the courtesy of The National Park Service.

STATUE OF THOMAS JEFFERSON IN THE MEMORIAL BUILDING
Left to right: OTTO R. EGGERS, ARCHITECT; DR. FISK KIMBALL, MEMBER OF THE EXECUTIVE COMMITTEE OF THE THOMAS JEFFERSON MEMORIAL FOUNDATION; STUART G. GIBBONEY, CHAIRMAN OF THE COMMISSION; SENATOR ELBERT D. THOMAS, VICE CHAIRMAN; RUDOLPH EVANS, SCULPTOR.

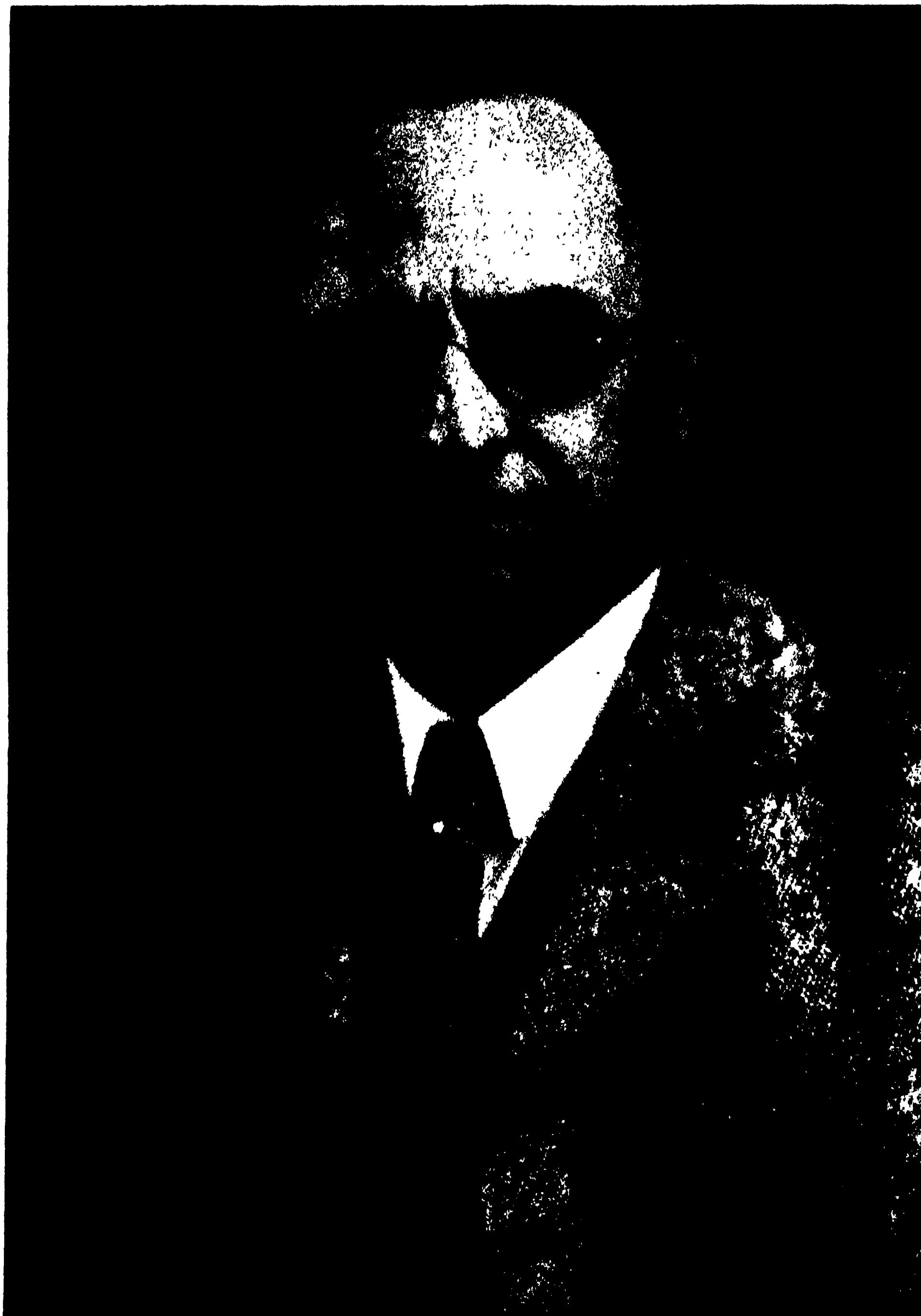
PRESIDENT ROOSEVELT SPEAKING AT THE DEDICATION ON APRIL 13.

"Under temptations and difficulties I would ask myself what would Dr. Small, Mr. Wythe or Payton Randolph do in this situation? What course in it will insure me their approbation? I am certain that this mode of deciding on my conduct tended more to correctness than any reasoning powers I possessed."



DEDICATION CEREMONIES OF THE JEFFERSON MEMORIAL

CHAIRMAN GIBBONEY AND MRS. ROOSEVELT ARE SITTING TO THE RIGHT OF THE PRESIDENT. THE UNITED STATES MARINE BAND STANDS IN FRONT OF THE GRAND STAND.



DR. WILLIS RODNEY WHITNEY

DR. WILLIS RODNEY WHITNEY, RECIPIENT OF THE JOHN FRITZ MEDAL[1]

It is unfair to any man to try to describe him by a single quality. He may be many things to different people: a loyal friend, an inspiring leader, a good fellow, an enthusiastic investigator, a pioneer, a practical realist.

Dr. Whitney is all of these. But his most conspicuous quality is scientific curiosity. He is a pure scientist, if we define pure science as that which is motivated by curiosity. I think Dr. Whitney would say that pure or impure is all the same to him; but that curiosity is the best basis for research of any kind. He once wrote: "The asset of engineering is exact knowledge. The valuable attributes of research men are conscious ignorance and active curiosity." His most frequent comment about research men is that they are not curious enough. The goal of research, he believes, is to find out how Nature works, rather than try to make it fit into our plans or theories. In his own words, "We advance more often by finding in Nature that which we may learn to use than by making or forcing from Nature that which we think we want."

The world will never know the full extent of Dr. Whitney's scientific contributions, because they are inextricably bound up with the work of those whom he directed. Stimulating suggestion was the feature of his daily rounds of the laboratory, but he claimed no credit for himself. I do not think it was so much conscious generosity, as a fundamental point of view. His philosophy of life calls for devotion to the search for Truth first, with personal considerations secondary and more or less immaterial as far as he himself is concerned. The fact that he nevertheless gained an undying reputation is one of the wonderful paradoxes of human psychology, perhaps one of the laws of Nature as fundamental as the physical laws which he sought to learn.

[1] Awarded jointly by a group of national engineering societies.

The work for which Dr. Whitney is best known is the organization and direction of the Research Laboratory of the General Electric Company. This was a pioneering task. Industrial research laboratories were not new, but their activities had been almost exclusively devoted to product development and improvement. Fundamental research was confined mostly to universities. Could it be done profitably in an industrial laboratory?

Mr. E. W. Rice, at that time chief engineer of the General Electric Company, had the vision that it could. He looked for a young man who might translate this vision into reality. He found Willis Whitney, a young assistant professor at M. I. T., who was having a fine time with his research and not at all concerned about another job, least of all a job of organization.

It was typical of Mr. Rice that he did not choose an organizer. Dr. Whitney is not an executive type. He hates routine. Conferences and committees bore him. Budgeting and bookkeeping are not among his interests. Nor has he that passion for being at the head of something, which characterizes many leaders. Yet he is one of the most successful leaders I have known. Perhaps the conventional method of leadership is not the only one, or even the best one. Inspiration and example may be more important than direction, at least in the realm of research. What Mr. Rice saw in Dr. Whitney was the scientist, whose enthusiasm for research was infectious. His faith in the man he chose never wavered.

The General Electric Laboratory was started as an experiment in industrial research; namely, a research laboratory that would include fundamental investigations as well as product improvement. That the two should go together is essential, since fundamental research leads to products, which must be nursed through

infancy before being passed on to the factory. There appears, however, to be a tendency, similar to the law of entropy, for laboratory activities to drift always downward toward practical applications. Dr. Whitney's success in stemming this tide, and keeping the balance between fundamental and applied science, is one of his great accomplishments. It attests his faith in the value of pure research, as well as faith in him on the part of the officials of the General Electric Company.

In organizing the laboratory, Dr. Whitney proceeded in the same manner as in his other scientific experiments. He began cautiously, on a small scale, feeling his way. During the first year, three days of each week were spent in Schenectady, and the other three in Boston. By the next year, the laboratory was a full-time job for him, with six assistants. Each year witnessed a small, well-consolidated growth, as in Nature. In this way, his own personality became indelibly impressed on the organization which grew up under his care. His fairness and strict honesty, thus transmitted, became the basis of the spirit of cooperation that has been the laboratory's greatest asset. His belief in the value of fundamental research, and his enthusiasm for experiment, have become part of that mysterious something which we call the spirit of the laboratory.

I can not remember ever having been reprimanded or criticized by Dr. Whitney. His method was encouragement. He almost never discharged an employee. Those who did not belong in the group came to realize it as a mutual condition, and left for their own interest.

In 1932, at the age of sixty-five, Dr. Whitney turned the direction of the laboratory over to Dr. Coolidge, thus finding opportunity to devote himself to experimental research, his first love. He comes to the laboratory every day. If I start early enough in the morning, I frequently have the pleasure of being picked up by him on his way to work, for he is still the first one in in the morning, as he has always been. To-day he is one of the gang. When he decides to stop coming to the laboratory, I think some part of him will still be there, inspiring and guiding our work.

ALBERT W. HULL

JOÃO BARBOSA RODRIGUES AND A NEW BRAZILIAN POSTAGE STAMP

MANY illustrious students of the abstract, the theoretical and the physical sciences have fittingly been honored for their accomplishments and their gifts to the advancement of human life and its comforts. A myriad of channels and devices have been utilized in bestowing these public compliments. Monuments have been erected, parks and even cities have been dedicated in the names of the students of the sciences. During the past decade a very effective medium of public compliment has internationally been employed with increasing frequency. Governments have given their sanction to the issuance of special postage stamps, individually designed for the single purpose of giving signal honor to great men and their deeds. These special pictorial messages, through the correspondence of the masses of the people, destined to the far corners of the globe, act as silent educators to the recipients wherever they may be.

Brazil has made good use of this broad medium of publicity to inform the world of her illustrious sons. By a 1942 decree, Getulio Vargas, President of the great South American land of coffee and rubber, of iron and cattle, of song and commerce and culture, authorized the preparation of a special postage stamp to do honor to a great scientist, the botanist Barbosa Rodrigues. His sixty-seven

THE BRAZILIAN STAMP HONORING THE BOTANIST, BARBOSA RODRIGUES

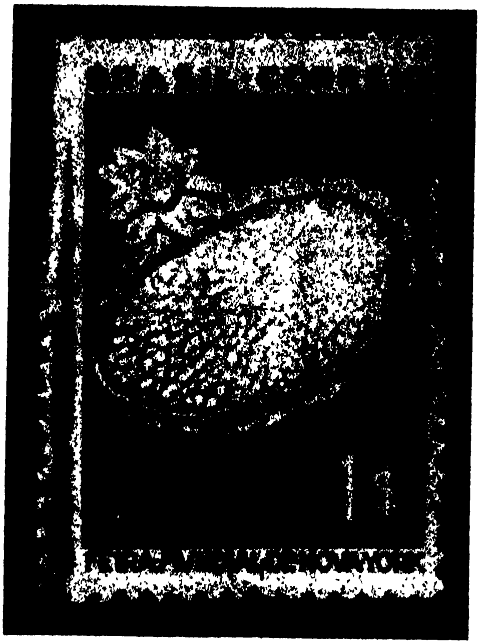
years were replete with research, study and accomplishment.

Born in Rio de Janeiro on June 22, 1842, João Barbosa Rodrigues was a naturalist of unquestioned merit. Judging, however, by some of the biographies that have come to light since his death on March 6, 1909, Barbosa Rodrigues in his early youth was more inclined to literature than to the serious studies of the botanical science. During his literary activities he wrote and published a number of books, short stories and novels that brought him fame as a popular writer; he also was the founder of a school journal called "Semana dos Meninos," considered the first of its kind ever to have appeared in Brazil.

He finished his course at the Instituto Comercial in Minas Gerais with highest honors of his class and was awarded a prize in economics. It was not until later, after he had finished his studies, that Barbosa Rodrigues devoted all his attention to the study of botany, archeology and anthropology. Except while he was at school he lived with his father of the same name, in São Goncalo de Sapucai in the Province of Minas Gerais where they had moved shortly after his birth. His father was a Portuguese subject and his mother, Maria Carlota da Silva Santos, was a Brazilian. She died while her son was a small boy, after the family had moved from Rio de Janeiro to Minas Gerais.

After his return to Rio de Janeiro, following the completion of his schooling, he was appointed Secretary of the Collegio Pedro II where he also taught drawing. While at this post he revealed his inherent tendency for the natural sciences in the study of which he acquired considerable knowledge. The Imperial Government of Brazil sent him to the Provinces of Para and Amazonas to make scientific investigations, especially in connection with the palm trees of those areas. In the course of his work Barbosa Rodrigues discovered and classified a large number of new species which had not been found by other scientists, among them the famous Martius and also Richard Spence and Alfred Wallace.

After having collected considerable data on the palm trees of the Amazonian



VICTORIA REGIA STAMP
SHOWING A FLOWER AND PLATTER-LIKE LEAF OF VICTORIA REGIA, A LILY OF THE AMAZON VALLEY, WHICH WAS STUDIED BY RODRIGUES. IN THIS REGION THE NATIVES GRIND THE SEED POD INTO A STARCHY FLOUR FOR FOOD.

region, Barbosa Rodrigues endeavored to obtain a subsidy from the Government of Brazil for the publication of the result of his investigations. He was, however, unsuccessful in this attempt. Meanwhile, Dr. Reichembak of Vienna, Austria, invited Barbosa Rodrigues to be his collaborator in the preparation of a tract on Brazilian orchids, a task that had been undertaken by the former some years prior but which he had been unable to complete due to his inability to locate the specimens for study in their native habitat. Some time after this, Dr. Eichler invited Barbosa Rodrigues to perform the same work with Dr. Kraenzlin, Reichembak's successor in Vienna. In his letter to Barbosa Rodrigues, dated July 22, 1881, Kraenzlin wrote as follows: "Les espèces nouvelles seront publiées sous le nom et l'autoriteé Barbosa Rodrigues and Kraenzlin ainsi que tout l'oeuvre. C'est a vous de dire oui ou non. Vous etes le premier et vous avez merité l'honneur."[1]

Two years after he had started his studies on this scientific subject and while still engaged in the work, Barbosa Rodrigues met Dr. James Trail, a British explorer who had come to the Amazon on a scientific mission for his Government. Barbosa Rodrigues informed the British representative of his discoveries in botanical fields and the two scientists "herborized" together. Some of the specimens that had been discovered, classified and drawn by Barbosa Rodrigues were sent to the Kew Gardens in London. Dr. Trail, however, claimed full credit in regard to these discoveries for himself and as a result Barbosa Rodrigues energetically proclaimed priority for his work. The subject was given consideration by the Instituto Historico e Geographico Brasileiro where Barbosa Rodrigues established beyond question that about the time Dr. Trail had arrived in Para, he himself had already studied and drawn the new species and submitted a detailed report to his Government.

In addition to the research in the flora and the fauna of Para and Amazonas, Dr. Barbosa Rodrigues undertook another task of wholly different character, namely, that of educating and Christianizing the Indians of the Crichanas tribe. His work has a strong tendency toward pacifying these warring Indians and raising their standard of civilization. In the conduct of this undertaking he studied the language and customs of the Crichanas and left several decidedly useful books in regard to both.

Dr. Barbosa Rodrigues is credited with being the first layman, unschooled as a physician or a chemist, to have made a

[1] "The new species, as well as the whole work, will be published under the name and authority of Barbosa Rodrigues and Kraenzlin. It's up to you to say "Yes" or "No." You have been the first and deserve the honor."—"Diccionario Bibliographico Brazileiro" by Antonio Victorino Alves Sacremento Blake, pp. 359–65.

thorough scientific study of *curare*, the deadly plant poison extensively used by the Indians in poisoning their arrows. He found that sodium chloride, common table salt, was an effective antidote for the lethal action of the violent poison which the Indians had so commonly used in battle. He also made numerous archeological explorations, and one of his most notable discoveries in that field was the *Muirakitan*, an idol of the natives who inhabited the Amazonian region long before Columbus arrived in America.

Dr. Barbosa Rodrigues was a prolific writer of books, reports and monographs on plants and archeology, still recognized by students of those sciences. Outstanding among his works, however, the following should be mentioned: "Enumeratio Palmarum"; "Sertum Palmarum"; "Genera et Species Orchidearum Novarum"; the last mentioned consists of seventeen volumes. He was a member of several learned and scientific societies and institutions of Europe, among them being the botanical societies of Vienna and Edinburgh, and also of the Instituto Historico e Geographico Brasileiro of Rio de Janeiro.

The 300 and the 1000 reis Brazilian stamps of 1937 dedicated to the Jardim Botanico, located about twenty minutes' drive from the metropolitan center of Rio de Janeiro, are closely associated with the life of Barbosa Rodrigues. Although founded long before he was born, the famous Garden was broadly expanded and developed while he acted as its director, beginning in 1890. Shortly after reaching Brazil in 1807 the Reigning Monarch, Prince Dom João (later King John IV of Portugal, Brazil and Algarves) ordered the preparation of a selected plot of ground for the development of botanical specimens. This was known as the Royal Botanical Garden and has since been renamed the Jardim Botanico and expanded until it now covers an area of some one hundred

JARDIM BOTANICO STAMP

DEPICTING THE AVENUE OF GIANT PALM TREES AND FOUNTAIN IN THE GARDEN. AT THE OTHER END OF THE AVENUE OF TREES IS A SMALL GREEK TEMPLE DEDICATED TO THE GODDESS OF PALMS WHICH WAS ERECTED BY RODRIGUES.

forty acres, being classed as one of the outstanding botanical preserves of the world. Its present beauty is due largely to the rearrangements, the monuments, the ponds and paths planned and perfected by Barbosa Rodrigues. Principal among these monuments is the Dea Palmaris, a small Greek temple dedicated to the Goddess of Palms, located at one end of a long avenue of giant palm trees which reach an average height of one hundred feet with a girth of approximately ten feet at their base. A view of this beautiful avenue of palms, terminating at one end with the Grecian temple erected by Barbosa Rodrigues and, at the other, with a beautiful double basin fountain, is depicted on the unusually attractive multi-colored Brazilian postage stamp of 1937. A delightful description of the Jardim Botanico is contained

in a well illustrated article by Dr. F. Lamson-Scribner in THE SCIENTIFIC MONTHLY of January, 1938.

One of the many botanical specimens which received the careful attention of Barbosa Rodrigues was the Victoria Regia which is depicted on an attractive dull violet 1000 reis postage stamp of Brazil, released during 1940 in compliment to the World's Fair in New York. The stamp shows one of the large circular leaves of the Victoria Regia which at times attain a diameter of from six to seven feet. The edges turn up at right angles to form a border eight or nine inches high, giving a platter-like appearance to the leaf and add appreciably to its strength. In addition to the leaf, largest in the lily family, the stamp shows one of the immense blossoms which generally reach the height of flowering beauty during the months of April and May in their native habitat of the Amazon Valley. The natives in the Amazon regions where the Victoria Regia grows in plentitude, use the pod as food, grinding it to flour which is said to contain a large percentage of starch.

A close analysis of the life of João Barbosa Rodrigues and the lasting accomplishments which glorify his memory, leads to many fields. Prime among them, however, his contributions to the development of the botanical science stand preeminent as those of a pioneer, a discoverer and an authority whose decision has but seldom been questioned.

Another outstanding South American botanist who has enjoyed the signal honor of portraiture on a postage stamp was Francisco Antonio Zea of Colombia. An accomplished naturalist, Zea was called to Bogotá at an early age to take charge of the National Botanical Gardens there, but his work in that direction was abruptly halted as a result of court action due to his having become implicated with Antonio Nariño in the publication of "The Rights of Man." Paradoxically, while in exile under order of the Crown's Judiciary, Zea won an appointment at the Botanical Garden of Madrid where he was designated and became famous throughout Europe as a professor of natural sciences.

A. B. TIGRE AND ALBERT F. KUNZE

THE USE OF AMINO-ACIDS TO SUPPLANT OR SUPPLEMENT BLOOD PLASMA

HUMAN blood plasma obtained from donors and injected intravenously has achieved widespread use in patients suffering from various diseases, in surgical shock from severe hemorrhage, and in burns. The relative ineffectiveness of injections of solutions of saline and glucose in such conditions is now generally known. Plasma owes its peculiar effectiveness, in large measure at least, to the fact that it contains in solution six or seven grams per cent. of protein which because of its large molecular size exerts a colloidal osmotic pressure. This property of plasma, as postulated by Starling nearly fifty years ago, is essential in order to maintain the circulation of the blood and a balanced fluid interchange between the blood and the tissues. In the majority of severe cases, at least one liter of plasma is required as an initial injection and such an amount requires the bleeding of four donors and considerable processing. Because of this inevitable practical difficulty and for other reasons, various solutions have been investigated in the hope that they could act as blood substitutes. For example, certain animal and vegetable proteins form colloidal solutions in water and could be used except for the well known fact that foreign proteins, when injected, produce dangerous anaphylactic reactions. Curiously enough, gelatin does

not have this effect and though tried in the past, it has not achieved general use because of many difficulties. Other substances, non-protein in nature (*e.g.*, acacia, pectin) also form colloidal solutions in water and thus simulate the behavior of plasma proteins. Although good results have followed their use, they, too, are foreign substances, and the body tries to get rid of them in one way or another.

An entirely different principle is involved in the injection of the simpler units of protein obtained by thoroughly hydrolyzing or digesting animal or vegetable proteins. The idea here is not to inject a solution which simulates the colloidal effect of plasma proteins, but to inject the common building stones of all proteins, *i.e.*, amino-acids and polypeptides, thus enabling the body to manufacture its own new plasma proteins or, indeed, proteins in any other part of the body. Nearly all protein can be hydrolyzed and will yield a mixture of amino-acids and polypeptides; if a proper protein is selected and appropriately hydrolyzed, the resulting mixture will contain all the essential amino-acids present in plasma proteins.

This approach to the therapy of diseases requiring plasma transfusions is essentially a biochemical or metabolic one. From such a point of view a fundamental fact is the inability of the body to replace rapidly the plasma protein loss in, say, a severe hemorrhage. The loss of the red cells has long been known to be of secondary importance to the loss of plasma itself. While the loss in blood volume is adequately restored from large extracellular stores of fluid, unfortunately this fluid carries little protein, and this little apparently is mobilized from the liver cells. Thus the loss of blood leads to a lowering of the colloidal osmotic pressure of the blood, and a week or more is required before it is corrected spontaneously. Consider how strange this is: following the loss of 2000 cubic centimeters of blood, a shift of an equal volume of protein-free fluid may restore blood volume, but this fluid lacks about sixty grams of plasma protein which is urgently needed and whose absence may prove fatal (or its injection may promptly save life). Yet at the same time kilograms of tissue protein are distributed everywhere without being used. The liver is probably a key organ in this situation because it is the manufacturing source of all endogenous plasma protein. After a severe hemorrhage the liver gives up what protein it can spare and become depleted, and must then make more protein from amino-acids or polypeptides, which in turn originate from the breakdown of other tissue proteins, unless, of course, it is supplied from without. It is this exogenous supply which offers a therapeutic approach.

Although the injection of hydrolyzed protein is a new method of therapy, it has already been used extensively as a means of intravenous protein alimentation in malnourished patients unable to take any food by mouth. Indeed, in such nutritionally depleted individuals, plasma transfusions were, until the introduction of hydrolyzed protein, the sole method of administering protein parenterally. In addition to its greater cost and inconvenience, plasma in such cases is actually inferior to hydrolyzed protein for other reasons, *i.e.*, amino-acids being basic building blocks, are able to supply means for correcting not only the deficiency in the blood stream, but deficiencies elsewhere in the body. Plasma, on the other hand, ordinarily corrects only protein loss from the blood; to be utilized outside the blood stream, it presumably must be hydrolyzed to smaller units and perhaps even amino-acids, before other tissues can utilize them for synthesis of their own characteristic protein.

Quite recently experimental studies seem to show that hydrolyzed protein may prove of value in more acute conditions, particularly when there is a sudden loss of plasma protein as from actual hemorrhage or injury. Such a use implies, of course, that the synthesis of new plasma protein can occur rapidly. Considerable evidence has accumulated especially through the work of Schoenheimer with isotopic nitrogen that the metabolism of protein is rapid. Those and other observations furnish a justifiable basis for the use of the building stones of protein in any condition where plasma protein is needed urgently. In the experiments just mentioned surgical shock was produced in dogs by repeated hemorrhage until a fatality ensued. The injection of solutions of hydrolyzed protein to replace the removed blood prolonged life significantly as compared with controls, even those in which citrated dog plasma was injected. The mechanism by which this result was achieved is not entirely clear, but was apparently made possible by enabling the liver to manufacture new plasma protein which permitted the subject to withstand further loss of blood. Thus, histological study of liver sections seemed to indicate that this was true.

Emphasis must be placed on the fact that the hydrolyzed proteins used thus far have no colloidal osmotic pressure and that they can not therefore be considered as a substitute for blood plasma in the true sense of the word. However, they offer considerable prospect of being valuable as a source of material from which the body may manufacture plasma proteins rapidly and thus spare the need for plasma. These observations, moreover, open an entirely new field of investigation which might be described briefly as the study of protein and amino-acid metabolism in conditions of stress and strain. For example, means may be found to accelerate the normal slow regeneration of protein which follows a severe hemorrhage. Viewed from another angle, nothing is known of the metabolic behavior of proteins which have been only partly hydrolyzed. The utilization of protein hydrolysates may be possible when relatively large aggregates of amino-acids are injected, aggregates which may even be large enough to exert some colloidal osmotic pressure of their own. Only further study will tell. Regardless of these considerations, there remains the practical superiority of solutions of hydrolyzed proteins which are available in unlimited amounts, and are almost as inexpensive to make and give as saline and glucose solutions, in contrast to the inevitable expense, difficulties and limiting factors in preparing plasma. Even if they can only supplement the need for plasma which is so effective in the acute stage of shock, the amino-acids of hydrolyzed protein offer considerable prospect of conserving much of the valuable plasma for more urgent purposes.

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NEWTON'S PHILOSOPHY OF NATURE[1]

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IT would seem to be a waste of time to discuss Newton's philosophy of nature, if the judgment of Professor Burtt is correct:[2] "In scientific discovery and formulation Newton was a marvelous genius; as a philosopher, he was uncritical, sketchy, inconsistent, even second-rate."

The opinion of Professor Burtt should rather read: Newton was of purpose not a philosopher, if philosophy be limited to a study of ultimate reality and the most general causes of things, as many modern metaphysicians wish to define it. The criticism has also its humorous side; since the author then proceeds to show that the ideas of Newton, *malgré lui*, are metaphysical. However, the reform of science instituted by Bacon, and completed by the genius of the seventeenth century, was founded on the thesis that science should not be concerned with ultimate reality and causes; since then, science has been more and more restricted to the enquiry of *how* things occur, and not of *why*. In other words, if there is a natural philosophy, it must be defined in its original and widest sense, as a love or pursuit of the knowledge of things, whether theoretical or practical.

It would even seem, according to a metaphysician, Newton was not a philosopher because of his "marvelous genius"; yet, to his contemporaries he was the "incomparable," because of his insistence that hypothesis should be no part of natural philosophy. My essay, to avoid even the semblance of erudition, will be concerned with what he contributed towards the downfall of the scholastic system, and the founding of modern science. But, I must insinuate that he provided the material for Locke's empirical philosophy.

The source of this break with the past was the conviction, widely and naïvely held during the seventeenth century, that our observation and reason, when properly exercised, are a sure guide to truth, an efficient key to unlock the mysteries of the material universe. For examples of any such unqualified conviction of truth, we must look to the Middle Ages when an infallible knowledge, derived from the Bible and the Church, was generally accepted; and, again, when in the latter part of the nineteenth century, the biologists, under the leadership of Spencer, Darwin, and Huxley, as confidently believed in the dogma of evolution for the elucidation of the origin and the phenomena of life.

There is abundant evidence that the scientific revolt of the seventeenth cen-

[1] From the symposium on "Natural Philosophy" commemorating the 300th anniversary of Newton's birth which was to have been presented at the New York meeting of the American Association for the Advancement of Science.

[2] *Metaphysical Foundations of Physics*, p. 203.

tury was a deliberate attempt to put into practice Francis Bacon's philosophy of induction. It is not necessary to discuss its principles at length, or the validity of its method; but rather its influence on seventeenth century thought. He tells us how, while yet an undergraduate student at Trinity College, Cambridge, he became disgusted with scholastic Aristotelianism as it was taught, because it had led only to barren disputation, and had through the centuries yielded no valuable fruit. He then, and there, resolved to establish a new philosophy, which would give to man the command over nature he had lost with the fall of Adam. Although his life was embittered by his frustrated ambitions and distracted by his public offices, he continued fitfully to work on his scheme to reform scientific method; but he did not even partially realize his cherished aims until he published, in 1620, the *Novum Organum,* the most important portion of his proposed *Instauratio Magna.*

Bacon, and his disciples, were convinced that the Middle Ages had left to them a legacy of argument on the causes of phenomena and very little knowledge of nature. He awoke their enthusiasm by the blunt statement that philosophy is not a science of things divine or human; it is not even the search for abstract truth; it is rather a practical seeking to improve our condition of life by increasing our power over nature and by forcing her to yield to us her fruits. "All depends," he affirms, "on keeping the eye steadily fixed upon the facts of nature, and so receiving their images simply as they are; for God forbid that we should give out a dream of our imagination for a pattern of the world."[3]

The only source of knowledge we have of the external world, Bacon claims, comes from the impressions made on our sense organs; and the only way we can obtain any guidance in the confused flux of events, which they present to us, is by systematic observation directed by our reason. This new method of induction is the only clue, a *filum labyrinthi,* by holding on to which we may safely and surely trace our way to knowledge and thence to power. "First of all we must prepare a *natural and experimental history,* sufficient and good; and this is the foundation of all."[4] Since we are sadly lacking in any adequate collection of data, the first requisite is to make careful and exact observations of phenomena, to record them, and then to classify them. In time, enough knowledge will have been acquired so that a grasp of the laws of nature will be attained. Nor, should this search for data be left to the whim of the individual; societies should be formed and, under the direction of the ablest leaders, should like a disciplined army go forth to win the battle for knowledge. This proposal to regiment scientists as an army was elaborated in his philosophical romance, *The New Atlantis.*

While it is true that Voltaire and the Encyclopaedists finally gave to Bacon the credit for instituting experimental philosophy, it was really Robert Boyle, followed by Newton and Locke, who implemented his ideas and made the final break with the scientific method of the Middle Ages, which Bolingbroke summed up as having been guided by "an inner sentiment of knowledge."

When Boyle, whose birth coincided with the death of Bacon as closely as Newton's with Galileo's, arrived in London in 1644 after his long exile on the Continent, the only relief he found from the anxieties of the Civil War was in his intercourse with what he termed the *Invisible College.* A number of the leading scholars of London had acquired the habit of meeting once a week to discuss matters of philosophy, and especially to foster experimental science. It was

[3] *Instaur,* Preface.

[4] *Cogitationes.*

largely the influence of these men which induced Boyle to devote his life to chemistry. Later, when the exigencies of war removed these Baconians to Oxford, he joined them; and with their sympathetic cooperation did the major part of his great work.

After peace followed the Restoration in 1660, the *Invisible College* was incorporated as the Royal Society. There is no doubt this Society was formed to carry out practically Bacon's experimental method. Bishop Sprat in his *History of the Royal Society* affirms it, and Sir Archibald Geikie in its *Record* of 1912 states: "The foundation of the Royal Society was one of the earliest fruits of the philosophical labours of Francis Bacon. The experimental method of research which that great man so strenuously expounded in his writings was a vehement protest against the deductive method which till then had been in vogue."

We may question whether scientists have adhered to the inductive method, or have confined themselves to experimentation and the derivation of laws; and we may doubt whether mediaeval science was the slave of deduction—certainly the alchemists, astrologers, and physicians made and recorded a great mass of observations. Yet the founding of the Society was, in a striking manner, the formal beginning of a new scientific era. By its motto of *Nullius in Verba*, its Fellows were pledged not to be bound by the dictates of any school of philosophy; they were to submit all questions to experiment; and they were to express all their findings in the simplest and clearest words possible so that scientific knowledge would become accessible to everybody, instead of being jealously concealed in the mystic phrases of the adept. Perhaps the purpose of the Society is most vividly illustrated by an anecdote. When St. Andrew was selected as its patron, the witty Dr. Petty grumbled: "I had rather have had it been St. Thomas's Day, for he would not believe till he had seen and put his finger into the holes." Such was then the confidence in observation as the key to absolute truth, and the popular translation of the motto had an early beginning.

Before discussing the particular ideas of Newton, it is advisable to state what is generally held to be the nature of the physical universe as it was conceived to be by seventeenth century natural philosophers. According to that mechanistic hypothesis, the cosmos is a vast machine; its individual parts are imperceptible and indivisible atoms whose essential attributes are mass, position, size, shape, geometric order and arrangement; its active principle is innate motion of the atoms, including rest, which operates according to rigorous law quite independently of man's desires and powers. The cause for changes of motion which produce variety was first attributed to collisions of the atoms; but, by the end of the century the force of universal attraction was accepted as the principle of action.

If we except the disciples of Hobbes, who saw nothing operating in the universe but blind chance and fortuitous motions of atoms, the general opinion was that the universe was created by a spiritual being; and its operations, had, once for all, been so exactly regulated by law that subsequent interference was rarely necessary.

This mechanistic conception of the universe was the logical conclusion from the work of that succession of astronomical physicists which began with the publication of Copernicus's *De revolutionibus;* and was the final phase of that Renaissance which reaffirmed the dignity of man's nature, and the importance of his earthly life for itself. There is no doubt of its fundamental break with the beliefs of the Middle Ages which

found in every act of nature the immediacy of God, who created the universe for the use and benefit of man, and who continually regulated it to that end. Law and order did not govern but rather the will of God and, to a less degree, that of man, to the extent that the miraculous was the commonplace; the orderly, the exception. The astrologers taught that the erratic motions of the planets were designed to affect our destiny, and the operations of nature. The alchemists thought prayer a necessary preliminary to the successful outcome of their manipulations. As late as the sixteenth century, Paracelsus, the iconoclast, warns us that prayer and a knowledge of the mystical formulae of the Kabbala were prerequisites for a chemist. To show the extreme view of this immediacy of God and of his purpose in creating the universe, Boyle quotes, with his disapproval, the opinion of a learned divine that, on the Day of Judgment, God would utterly destroy the universe as no longer of any use; mankind having finished its probation. Observation and reason were regarded as but frail supports, in comparison with the infallible revelation of the Bible and the decrees of the Church.

The mechanistic hypothesis was revolutionary rather than original, since it was a revival of the ideas of the Greek philosophers who, with the exception of Socrates and Plato, and to a less degree of Aristotle, derived their ultimate cause from "some inherent law of matter and spirit, which leaves no place for the reality of Ideas, or for a conscious Creator, or for cosmic purpose."[5] Nor, in this respect, is there much difference between the chance results of the atoms of Epicurus rushing fortuitously through the void, and the deterministic *tonos* of Zeno alternately expanding and contracting in an infinitely continuous medium.

We may assume with considerable certainty that, if the Greek culture had persisted and flourished, the discovery of the phenomena and laws of nature would have increased steadily; a clear and simple phraseology would have developed; and natural philosophy would have progressed along mechanistic, or deterministic, lines. Such, at least, the leadership of Euclid, Hipparchus, Archimedes, and others, foreshadowed. But, the collapse of the classic civilization, the intrusion of barbarian hordes, and the impact of the Christian religion with its emphasis on other-worldliness and its reliance on revelation, practically destroyed all interest in systematic enquiry for centuries and, to a large extent, obliterated the scientific knowledge which had been accumulated.

Anyone who has tried to unravel the intricacies of alchemy and astrology during the Middle Ages, can only be filled with wonder that the followers of those sciences acquired as much of useful knowledge as they did. Only the crudest apparatus was accessible to them; no phraseology better adapted to conceal knowledge could have been devised. Dominated by the belief in the influence of the planets on life, and by the search for the magic of the philosopher's stone, a bewildering system of mysticism was built up which distracted the attention from the legitimate purposes of science.

Lastly, a distorted application of Aristotle's metaphysics had, by means of translations and commentaries from Syriac and Arabian sources, been introduced into Europe. This pseudophilosophy of nature gradually became so unquestioned as to be of almost equal authority with the Bible and the Church. Each product of chemical analysis or synthesis was characterized as a compound of different proportions of Aristotle's four essential elements—earth, water, air, and fire. Since there was no agreement as to what these ideal elements represented, there could be no agreement as to the nature or constitution of bodies. Added to this confusion, the alchemists'

[5] P. E. More, *Sceptical Approach to Religion.*

chief interest was concerned with the transmutation of metals, and they chose a philosophic mercury as their principal stuff. By hypothesis, to change one metal into another, say tin into silver, one must detach the specific qualities from the tin which left essential mercury as a residue; then add consecutively the properties of silver. The valuable reagents, acids, alkalis, alcohols, discovered in their operations were regarded as of little importance, except as they related to their absorbing purpose. The major operations for transmutation were repeated distillations and prolonged heating, and the most accepted criterion of transmutation was the right succession of colours. Continual discouragement, arising from the failure to obtain practical results from this logical hypothesis, gradually induced alchemists to seek supernatural help. Some resorted to black magic and sold their souls to the devil in exchange for power; others enlisted the assistance of God by prayer, and by a pious life; but all eagerly sought the mysterious philosopher's stone whose mere presence accomplished the impossible task.

To account for the various attributes of body, recourse was had to Aristotle's category of the formal cause by which potential substance received actual, ideal form. Thus, a body was red because it contained the substantial form of redness; and, frequently, these substantial forms were regarded as entities distinguishable from the bodies themselves. When scientists were confronted with a mystery, such as the levitation of water in a suction pump, they could always rely on nature's abject horror of a vacuum, which Aristotle had declared to be unthinkable, to come to their aid.

Such in bare outline was the prevailing philosophy of nature until the sixteenth century, when a new school of chemistry was founded, under the leadership of the mystical iconoclast, Paracelsus, who introduced the use of chemical drugs, and advocated a greater reliance on experimentation. The major change in philosophy, which these Spagyrists proposed, was the substitution of three hypostatic principles—passing under the names of essential salt, sulphur, and mercury—for the four scholastic elements. The change was of little value, since no one could define what the symbolic principles meant. What notably happened was a bitter controversy between the conservative school of the Peripatetics, which had "not been very solicitous to gather experiments" to prove their doctrines because they relied on pure reason, and the upstart Spagyrists, scornfully dubbed "sooty empirics," who had bleared their eyes, and befuddled their brains, with the smoke of their furnaces.

In fact, instead of clarifying and simplifying science, there followed a deterioration in the whole fabric of its philosophy. Until the sixteenth century, however much scholastic alchemy may have been obscured by an infusion of religious mysticism, and made abortive by a fantastic nomenclature, the alchemists as a body were endeavouring to discover the properties of metals by scientific method; nor were they fraudulently exploiting their work for illicit wealth. But in that turbulent century there developed a radical, and two-fold, change in the aspect of alchemy which caused its efflorescence in the next century as a social and religious menace; and its collapse in the eighteenth century. As a social evil, the transmutation of metals was exploited by individuals, and even by governments, solely as a means of securing unlimited wealth; as a mystic cult, the science degenerated into a grotesque allegory of the sacraments, and of the redemption of man, by an almost blasphemous identification of the philosopher's stone with the Christ, the corner-stone of the Church.

It had become evident that mediaeval science had outlived its usefulness; but it required the effort of a great creative century to bring order out of the chaos. The institutors of the new mechanistic philosophy were Robert Boyle (1627–1691), John Locke (1632–1704), and Isaac Newton (1642–1727); of the three, the chief credit must be assigned to Boyle. Although they were so nearly of an age, he had established his commanding reputation, and had practically won the battle, by the publication of his *Spring and Weight of the Air* in 1660, and the *Sceptical Chymist* in 1661. Nor, was his leadership challenged for thirty years, until the appearance of Newton's *Principia* and Locke's *Essay concerning Human Understanding.*

Thus, thanks to the labors of Bacon and Boyle, Newton had ready made for him a philosophy, exactly suited to his temperament. He was essentially an experimentalist; and he greatly exceeded his predecessors in his faith in experiment rather than in hypothesis, which he finally excluded altogether from the field of science. The mechanistic philosophy afforded him also full scope for his unrivalled mathematical genius, since the problems of position and motion are capable of geometrical formulation. To these two traits, we must add his love of meditation. Apparently, he felt no inclination, or obligation, to make public any of his great discoveries. The mildly critical reception of his letter on the composition of white light so puzzled and exasperated him that he seriously threatened to forsake science; and he carried out this resolve to the extent of publishing willingly no other important work.

What we must rely on, for Newton's personal ideas on natural philosophy, are his letters to friends and scattered comments in his works; but there is one notable exception. In 1704, he published his *Optics,* at the desire of some gentlemen of the Royal Society; although, to avoid disputes he had wished to delay its printing. "My design in this book is not to explain the properties of light by hypotheses, but to propose and prove them by reason and experiments." And, in spite of his professed desire to avoid disputes, he appended two short mathematical tracts in such a way as to accuse Leibniz of plagiarism. As a result of the bitter accusations of Leibniz and his friends, he omitted the tracts in the second edition, "as not belonging to the subject." In their stead, he added at the end of the book, devoted to experiments, "some questions; and to shew that I do not take gravity for an essential property of bodies, I have added one question concerning its cause." It was an odd place for such questions, since they are, in fact, his speculations on the cause and nature of light, gravity, the aether, and radiation, or effluvia. We should never have had his profound reflections on such matters, if he had not been stung to the quick by the Leibnizians, who accused him of promoting atheism and of being as hypothetical in his ideas as others were. Since Boyle had elaborated the mechanistic philosophy in such detail and so sympathetically with Newton's ideas, a short outline of his work will be given as a background for that hypothesis.

Boyle, when a youth, had been converted to the Baconian philosophy by his association with the *Invisible College.* He heard much lip service to the new method, but he also saw little effort to practise its precepts. He determined to devote his life to compare the tenets of the Peripatetic, the Spagyristic, and the mechanistic hypotheses, with experiments, and to foster that one which best stood the test. To carry out this apparently revolutionary idea, he migrated to Oxford in 1654. For six years, he prepared himself for this laborious undertaking. He associated himself with a

small coterie of the ablest scientists in England; he put himself under tutelage to change himself from an amateur to a professional chemist; he equipped laboratories and employed secretaries, amanuenses, and assistants, of whom one was Robert Hooke. As a small army, under his generalship, they were to follow literally Bacon's advice, and compile histories of the physical sciences, which would make accessible, in the simplest and clearest phraseology, all the experimental facts which they would discover, and which they could gather from other sources. With the evidence from these histories, as a beginning, accurate knowledge would be accumulated from which natural laws would evolve, and the most rational philosophy would be developed.

Between the years 1660 and 1673, Boyle published fifteen treatises—experimental histories on the air as a body, on color, on cold, on effluvia or radiant energy, and on many other topics—and exhaustive discussions of the three principal philosophies of nature. The success of Boyle was, I think, without parallel in scope and results in the history of science. His histories were the true beginning of scientific memoirs and of collections of tabulated data; the Aristotelian elements, and the Spagyristic hypostatical principles simply vanished; and with them went the mediaeval conception of substantial forms, *horror vacui,* and the miraculous, as active agents.

As a philosophy of nature, he advocated the acceptance of the atomic and mechanistic hypothesis as recently revived by Gassendi; but he would always remain the sceptic, forbearing to endow the corpuscle with any specific qualities except mass and simple geometric properties; and even these simple metaphysical postulates were to be considered only as guides to thought: "Whether there be any one such body [*i.e.,* corpuscle] to be constantly met with in all, and each, of those that are said to be elemented bodies, is the thing I now question." True to his purpose of creating experimental chemistry, he defined for practical use an element as follows: "I now mean by elements—certain primitive and simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the ingredients of which all those called perfectly mixed bodies are immediately compounded, and into which they are ultimately resolved."

As cause of action, he could conceive of no other except corpuscular motion and rest, and he deprecated the invention of a substantial form to account for each secondary quality of matter, such as color, tone, temperature. He classed all these forms of radiant energy in the category of effluvia. He hesitated between the idea that an effluvium is caused by special corpuscles expelled from a body, or whether it is the result of motion of bodily corpuscles transmitted through an aether, as pulses or waves, or a combination of both.

The distinction of a primary quality as one which is inherent in body, from a secondary quality which is accidental and serves merely to distinguish bodies, is an artificial and hazardous assumption. It can be justified by the mechanist only as an arbitrary limit he imposes on the problems he chooses to investigate; and that limitation has its advantages.

A little consideration will make clear that the distinction of primary and secondary qualities as a fact of nature is a false one. If Boyle assumed color is the result of special corpuscles, which can differ from the corpuscles of bodies only in the degree of their primary qualities, then he is, in fact, postulating color as an entity, or substantial form. If he chose to postulate color as the effect of motion in an aether, in what manner does aetherial motion differ from the primary quality of a bodily motion,

or the aether itself from a substantial form. Nor is this an academic question. Are not our modern hypotheses of electrons as body, of wave mechanics, of quanta of energy, of packets of light, a revival of mediaeval substantial forms of occultism? So difficult is it for scientists, who profess to rely on observation, to refrain from creating and materializing an occult entity to account for what they can not comprehend. They too often forget Maxwell's sound dictum that the atom, however disguised, has all the ear-marks of being man-made.

Boyle made a complete cleavage between phenomena of the material and spiritual worlds. The Christian God was the creator and ruler of both; and man, as a unique creation, was endowed with such powers of observation and reason as to understand the purpose of both to a limited degree. The material world was created to operate under rigorous mechanical laws unaffected by man's desires, at least for the most part; but Boyle was sceptical as to the absolute rigor of these laws, and credited miraculous intervention as well as slight variability. Instead of promoting atheism, the mechanistic hypothesis, if rightly interpreted, should be a strong support of the Christian religion, since God revealed his nature and his purpose towards man through his ordained laws of nature.

But, in Boyle's conception, since the spiritual nature is nobler than the physical, and moral character more valuable than mechanical power, so science is necessarily of a lower degree than religion. Therefore God had given to man a more authoritative revelation of his purpose of creation in the Bible than he had in the Book of Nature, and to implement that revelation he did not hesitate to change physical law temporarily by fiat or because of the legitimate petitions of men.

Although man, being finite in his apprehension, can not grasp the whole scheme of things entire; yet he can attain a real knowledge of phenomena and their efficient cause, and even to a limited degree the final cause and purpose of the creation. He apparently had no doubt that experimental observation revealed the phenomenal world as it really is. It is a mournful commentary, that it has taken us some centuries to recognize the paradox of science that the more accurate our apparatus, and the more carefully our observations are made, just the more certain and evident our errors will be; so that at last we have formulated, with some complacency, the principle of uncertainty as a *law* of nature.

Nor did Boyle hesitate to trust to the same method of obtaining truth in the spiritual world. He was a leader in the Deistic branch of the Anglican Church which followed a *via media* between the Romanists who could not err, and the Calvinists who would not. While he denied the infallibility of the Bible and of the Roman Church, and the inerrant logic of Calvin, he agreed with the Deists that those matters necessary for salvation are so few and so simply stated in the Scriptures that we can apprehend them. Alas again, time has proved that even what is necessary for salvation is a matter of infinite dispute.

The great productive period of Boyle, 1660–1673, coincides exactly with the years of Newton's life, when, as he remarked, his mind was most active, and his inventive genius at the height of its creative power. He entered Trinity College in 1660; he spent from August 1665, to March 1667 at Woolsthorpe, where he invented the calculus, discovered the laws of gravitation and the composition of light; and, in February, 1672, he sent to the Royal Society, his *Letter*, containing his new theory of light and colors—"being in my judgment the oddest, if not the most considerable detection, which hath hitherto been made in the operations of nature."

It will hardly be denied that the philosophic bias of a man is largely determined by his temperament, and that his success is dependent on its being in sympathy with contemporary ideas. If we can impute Boyle's influence to the fact that, as the first modern experimentalist, he was in accord with the prevailing "climate of opinion," we must class Newton as a supreme example of that type of mind. While Boyle was diffuse in his interests, Newton was concentrated and, having begun to meditate on any subject, he never let it lapse until he had wrung out of it all he could. Not only was he a greater experimentalist than Boyle, but he also was endowed with an incomparable mathematical genius. But he used mathematics only as a tool; as an end in itself, he considered it a dry and barren subject, and tending to involve one in useless speculation, or hypothesis. In his conviction as to the sterility of scientific hypothesis, he far exceeded the precepts of Bacon, and the practice of Boyle. Nothing angered him more than to accuse him of introducing occult causes in the *Principia*. As an answer to this charge by the Cartesians, he retorted that his system was founded on experimental evidence, and developed with mathematical rigor; and for that reason, "the hypothesis of vortices is pressed with many difficulties."

Not only did Newton believe that the first commandment of science was that theory must be based on experimental facts, but he also was ready to abandon his cosmic theory without hesitation if it lacked that support . . . ; "After he [Molyneux], and Mr. Graham and Bradley had put up a perpendicular telescope at Kew to find out the parallax of the fixed stars, they found a certain nutation in the earth which they could not account for, and thought destroyed the Newtonian system—M. told I. N. as gently and tactfully as he could—But all I. N. said in reply was, 'It may be so, there is no arguing against facts and experiments.' "[6]

Because of Newton's discovery of the universal force of gravitation, and the unparalleled influence of his *Principia,* he is popularly, and erroneously, regarded as the dictator of a universal machine ruthlessly governed by rigorous geometric laws and in which man is reduced to be a puny and impotent onlooker. If, however, we examine this work critically, we shall find that, except for a short and formal statement of abstract mechanical principles as an introduction, the body of the work is an exposition of Bacon's inductive philosophy as it was experimentally developed by Boyle.

Newton, in his *Preface,* makes his purpose clear that he is considering a very restricted category of problems; namely, those which obviously involve only position, motion, and a mechanical force, all of which are quantitatively expressible in geometric propositions and theorems. Furthermore, in agreement with this purpose all other qualities of body are abstracted excepting mass, a numerical coefficient equal to the ratio of the mechanical force, and the acceleration it produces.

Newton expressed his purpose with such care that the passage is quoted: "Since the ancients (as we are told by Pappus) made great account of the science of mechanics in the investigation of natural things; and the moderns, laying aside substantial forms and occult qualities [Note the influence of Boyle], have endeavoured to subject the phenomena of nature to the laws of mathematics, I have in this treatise cultivated mathematics so far as it regards philosophy." Taken by itself, this statement would justify the idea that he embraced the whole of objective phenomena; but not so, if we read further:

6 *Portsmouth Papers.* Memorandum by Conduitt.

"We consider chiefly those things which relate to gravity, levity, elastic force, the resistance of fluids, and the like forces, whether attractive or repulsive; . . . to this end the general propositions in the first and second books are directed. In the third book, we give an example of this in the explication of the System of the World; for by the propositions mathematically demonstrated in the first book, we there derive from the celestial phenomena the forces of gravity with which bodies tend to the sun and the several planets. Then from these forces, by other propositions which are also mathematical, we deduce the motions of the planets, the comets, the moon, and the sea. I *wish* we could derive the rest of the phenomena of nature by the same kind of reasoning from mechanical principles; for I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards each other, and cohere in regular figures, or are repelled and recede from each other." How far he succeeded in his "wish" to apply mechanical principles to the phenomena of light, will be discussed later.

Shortly after the *Principia* was published, Newton was charged with having, himself, introduced occult qualities, or substantial forms; and, more seriously by Leibniz, that he had encouraged atheism, because his God was at most merely an indefinite being who created an universal machine, which was self-acting and needed but a mechanic to keep in repair. To the charge of occultism, he answered, that his system involved only such principles as *Vis inertiae*, gravity, fermentation, and cohesion. These are not occult qualities, as were substantial forms and vortices, because they are observable phenomena. Their causes are occult and, for that reason, speculation in regard to such causes had been excluded from his work.

As to the charge of atheism, it should be remembered that Hobbes had aroused a great controversy in England; such leaders of science, as Boyle and Newton repudiated his materialism as atheistic, and were sensitive lest their ideas should be confused with his: hence the *Boyle Lectures against Atheism*, and Newton's *General Scholium*. It also should be remembered that Leibniz was then smarting under the accusation of plagiarism. Newton was certainly not an atheist, but his views on Christian dogma are puzzling. All his life Newton remained a professing member of the Anglican Church. He was an incessant reader of the Bible, believed in a spiritual and personal God, and in his miraculous interference in man's behalf. Yet he was privately a Unitarian, and rejected the doctrine of the Trinity, on the ground that what could not be understood was not necessary to be believed. This conflict between Christian dogma and practice was frequent at that time, and must always result from an attempt to rationalize religion.

Newton was emphatic that the universe was created by a spiritual Agent, who, having planned and instituted adequate mechanical laws, had little need to interfere in their future operation. Thus, to investigate these laws was to learn in part the purpose and plan of God; but, his laws and relations with man are revealed in the Bible.

Our knowledge of objective phenomena, Newton thought, was brought to us by mechanical motion to the sense organs, and from them transmitted along the nerves to the brain. The translation, and interpretation of these messages were made by an immaterial entity, spirit, or soul, located in the brain and which, following Henry More, he termed the sensorium. This association of an immaterial entity and of body was a frequent device. Descartes placed the mind in the pineal gland; Boyle regarded the union of the soul and body as the great-

est of mysteries, to be accepted only on faith.

Before Bentley published his Boyle Lectures, he wrote to Newton that he had supported his argument for the existence of a Divine Creator on evidence from the *Principia;* and he asked whether the universe could have been created by natural powers.

Newton answered: "When I wrote my treatise about our system, I had an eye upon such principles as might work with considering men, for the belief of a Deity." He then answers Bentley's question, by first postulating matter to be uniformly distributed through all space in the beginning, as the atheists had supposed, and all the particles to be mutually attractive. If space is finite, he thought all the matter would drift to one centre and form a great spherical mass. If space is infinite, there would be no centre and some matter would fall to one point, and some to another, and thus make the stars.

It is evident that Newton had given little thought to the problem, for he became critical of his opinions as the correspondence continued. Finally, after many attempts, he concluded that the postulate—afterwards assumed by Kant and Laplace—was "inconsistent with the hypothesis of innate gravity, without a supernatural power to reconcile them; and therefore it infers a Deity." It was of this correspondence, that Dr. Johnson remarked: "Even the mind of Newton gains ground gradually upon darkness."

Later, to meet the accusation of atheism, he made his confession of faith in the *General Scholium* to the second edition of the *Principia:* "This most beautiful system of the sun, planets, and comets could only proceed from the counsel and dominion of an intelligent and powerful Being. . . . As a blind man has no idea of colours, so have we no idea of the manner by which the all-wise God perceives and understands all things."

All the bodies forming the universe are, according to Newton, composed of discrete atoms, which are endowed with the primary geometric qualities, first proposed by Galileo. But he also endowed bodies with an additional quality, a fact which historians have overlooked. His third definition of motion reads: "The *vis insita,* or innate force of matter, is a power of resisting, by which everybody, as much as in it lies, *endeavours* to persevere in its present state. . . . This *vis insita* may, by a most significant name, be called *vis inertiae,* or *force of inactivity.*" The acceptance of a vitalistic principle, perhaps, was influenced by Henry More, whose philosophy was based on the necessity of spiritual forces in the operations of the physical world.

Newton had made the supreme discovery of universal attraction, with which to replace mere motion as the active agent of phenomena. But, he was deeply impressed by the lack of evidence of a repelling force to give balance and stability. He even went so far as to suppose the existence of a most subtle Spirit which pervades and lies hid in all gross bodies. In seeking for an illustration of this Spirit, he notes the fact that "electric bodies operate to greater distances, as well *repelling as attracting* the neighbouring corpuscles." Then he cautiously adds, we have not the experimental evidence "which is required to an accurate determination and demonstration of the laws by which this *electric* and elastic Spirit operates."

This invocation of a subtle Spirit to explain any perplexing phenomenon is a time-worn custom. Once a personal demon or angel, it passed into the form of a philosopher's stone or a universal elixir; then, it reappeared as an exhalation or effluvium of a mysterious nature. When Boyle proved that air was no more occult than any other body, effluvia were stripped of their spiritual powers, and became aethers which accomplished their functions by mechanical action.

Newton was a convert to the Boylean aether, and wrote to him, his idea of its nature: "I suppose that there is diffused through all places an aetherial substance, capable of contraction or dilatation, strongly elastic; and, in a word, much like air in all respects, but far more subtile. I suppose this aether pervades all gross bodies, but yet so as to stand rarer in the pores than in free spaces; and so much the rarer, as their pores are less [or the bodies are denser]." To understand the better the enthusiasm aroused by the substitution of a gaseous and corpuscular aether in place of more apparently mysterious Spirits, we should recall the equal relief caused by Maxwell's theory of electrodynamics, and the change of a gaseous, into an electromagnetic, aether.

When Newton allowed himself to relax the limitations he imposed on the scientific method, he was an imaginative and daring speculator. Of the many illustrations he cites in a private letter to Boyle, to show how he would use the aether to explain phenomena, those for gravity and light will suffice.

Newton first devised an experiment to prove that gravity is not an innate quality of matter. He found that the period of a pendulum was quite independent of the kind of matter composing its bob; and he concluded that the attraction of the earth was independent of any specific properties of the corpuscles. He then enquired into the possibility whether the aether described above could, by its pressure, cause attraction. He, first, assumed that the aether, between two bodies, progressively rarefies as they approach each other. By an explanation too long and intricate, and I may add too vague, to be quoted, he satisfied himself that the pressure of such an aether would account for their attraction; also, it would produce a repulsion, when they approached very closely to each other. In justice to Newton, I quote from his letter: "The truth is, my notions about things of this kind are so indigested, that I am not well satisfied myself in them; and what I am not satisfied in, I can scarce esteem fit to be communicated to others, especially in natural philosophy, where there is no end of fancying."

It is often stated that Newton, by adopting the corpuscular theory of light, retarded progress in the subject for a century. But, it should also be remembered that he carefully considered the possibility of its propagation by aetherial waves. In order to obtain a relation between the properties of a gas and the velocity of wave transmission through it, he made a careful determination of the velocity of sound through air, and discovered the law that $V = \sqrt{e/d}$. Since the velocity of light was then computed to be 700,000 times that of sound, he concluded that "the elastic force of this medium, in proportion to its density, must be above $700{,}000^2$ times greater than the elastic force of the air is in proportion to its density." It was not the staggering properties of such a gas which made him discard the wave theory, but rather the impossibility of explaining the newly discovered polarization of light as a property of a compressional wave. The later assumption of a transverse wave in a gas may have solved the problem of polarization, but it was ultimately the death of the luminiferous aether. Such violent assumptions, to explain a particular phenomenon, were absolutely repugnant to him.

Having decided in favor of the corpuscular theory, Newton was free to speculate on its effects. A multitude of light corpuscles occupy the pores of a body and, by their motion, agitate its corpuscles to cause the phenomena of heat. When they are expelled from a body, they travel through space as rays of light. If they fall upon the retina of the eye they cause a vibration in it which proceeds along the nerve fibers, and are

translated by the sensorium as color—the longest vibrations as red; and the shortest as violet. Also, these rays of light set up waves in the gaseous aether which travel faster than the rays and give to them alternate fits of easy refraction and reflection when they strike a body.

Since light, aetherial, and bodily, corpuscles differ only in degree, and not in kind, there should be a mutual gravitational action which will deflect a ray of light as it passes close by a body. Are not, he asks, gross bodies and light convertible into one another? Such a process "is very conformable to the course of nature, which seems delighted with transmutations," as Mr. Boyle proved when by frequent distillations he changed water into fixed earth. These illustrations may show what Newton could add to the metaphysics of nature, and I esteem him as fertile in fanciful speculation as, for example, Sir Arthur Eddington.

I have, for the most part, discussed what Newton would have slightingly termed his hypotheses; his greatest contribution to the philosophy of science was made in 1673, at the beginning of his career. I am referring to his *New Theory of Light and Colours.* I had often wondered why he, so persistently reticent, should then boastfully claim to have made the greatest of scientific discoveries. Yet, he must have known that his discovery of the law of gravitation, as a new fact, far out-weighed that of the nature of white light. I am convinced his enthusiasm was aroused because he realized that he had for the first time brought one of the secondary qualities of matter into the field of geometry and mechanics; that he had given final authority to empirical science; and that he had determined the limits of scientific, or at least quantitative, experimentation. Since I dwelt on this idea at some length in my *Life of Newton,* I shall now limit myself to a short extract from that argument.

Newton, in the first place, refused to give an hypothetical explanation of color and, in the second place, he refused to adopt the psychologic, or subjective, sensation of color as a criterion for physical, or objective, phenomena of light. To him, as a physicist, a primary ray of light was one which had a definite angle of refrangibility, and could not be decomposed by a prism, irrespective of what sensation of color it might cause. Hooke's classification of red and blue as primary colors, because, when mixed, they gave the sensation of white, were no more primary according to Newton's mechanical criterion than were any other non-dispersive colors; nor was that *white* physically the same as the *white* of the continuous spectrum. This may seem to be a trifling difference, but it involves the essential problem of what constitutes the scientific method, if it be defined as an objective investigation of phenomena. To the physicist, the problem ends when light energy is physically absorbed by retina; for the psychologist the problem begins with that absorption. What happens by which that energy is translated into color is a process to which science can give no clue.

A short discussion of the effect of the mechanistic philosophy, as a whole, on subsequent thought is the proper conclusion of this essay. Quoting from Basil Willey's *Seventeenth Century Background:* "Though there is no diminution in the volume of praise which is bestowed on the giants of the seventeenth century—'the century of genius'—there is no longer the old tone of expansive optimism, the glad sense of final escape from error. Though no one denies the extent of our gains, it is more often of our losses that we are now reminded."

Of our losses, Professor Whitehead writes:[7] Nature according to the mech-

[7] *Science and the Modern World,* Ch. III.

anistic philosophy "is a dull affair, soundless, scentless, colourless; merely the hurrying of material, endlessly, meaninglessly. However you disguise it, this is the practical outcome of the characteristic scientific philosophy which closed the seventeenth century. No alternative system of organizing the pursuit of scientific truth has been suggested. It is not only reigning, but it is without a rival. And yet—it is quite unbelievable. This conception of the universe is surely framed in terms of high abstractions, and the paradox only arises because *we* have mistaken our abstractions for concrete realities. . . . Thereby, modern philosophy has been ruined."

I agree fully with Professor Whitehead that the mechanistic philosophy, as it has been enlarged and developed since the seventeenth century, has, on the whole, been disastrous to society; and especially to religion. But, on whom, is to be placed the blame; certainly not on its institutors? No, the blame rests squarely on their successors who, either ignorantly, or wilfully, extended it to disciplines and fields of thought which Bacon, Boyle, and Newton would have utterly rejected as mechanical or material. They omitted from the science our sense perceptions of color, scent, sound, because such sensations are not mechanical. They, also, first recognized that such sensations are preceded, even if not caused, by phenomena involving objective body, force, and motion, or kinetic energy as we now class them together. They, and most physicists since then, have restricted themselves to the study and applications of this mechanical energy with eminent success. Nor, is it surprising that they, quâ mechanists, class certain qualities as primary for their purpose, and others as secondary. Is there any other method of studying a given subject except by such abstractions? Is not a theologian permitted to treat the Christian religion, and to regard other faiths as of secondary importance? It may be unfortunate to be limited in capacity but, perhaps, the persistent attempts of metaphysicians to embrace all knowledge in a single frame is a part cause of their incoherence and ambiguity.

In its own field, the science of mechanics has been so successful and so exact that it has been extended to other sciences verbally, but not factually. It was not the mechanistic physicists who made the mechanistic philosophy "not only reigning, but without a rival." It was the biologists, who have pictured life as a mechanical evolution of matter; the psychologists, who have identified sensation, thought, and the soul, with mechanical energy; the sociologists, who have tried to substitute rigorous social laws for individual responsibility and freewill; and who have degraded Christian ideals of other-worldliness to a humanitarian hedonism. It is these scientists and monistic metaphysicians, who have ruined modern philosophy.

CHINA AND AMERICA AGAINST SOIL EROSION

II. LOSSES AND GAINS

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In the first part of this paper, which appeared in The Scientific Monthly for May, 1943, we have shown from observations and experiments of the senior author what has led to destructive erosion and damage by floods. These facts were found near the headwaters of the Fen River in Shansi, China. We have also presented evidence from printed Chinese records studied and translated by the junior author regarding the area of the sacred mountain Wu-t'ai Shan, about fifty miles to the east, and other areas in the northern part of the province, which traces the course of land use through 1,800 years. In spite of once successful measures for conservation, deforestation of slopes and erosion of cultivated fields have irreparably damaged large areas and induced destructive regimens of the streams.

Similar experiments were carried out and records examined for other areas in the same province which are now to be discussed.

Similar Reports from Other Areas

Passing southward to the west of the Fen River we next consider three adjoining districts with steep, mountainous topography. Lan Hsien extends on both sides of the divide between the Fen and Yellow Rivers, while Hsing and Fang-shan Districts are west of the divide. The rainfall is in general convectional in type, and is heavier than in most parts of Shansi because of the altitude, 9,000 feet (2,870 meters) at Kuan-ti Shan. Loess soils cover elevations up to 5,000 feet, above which mountains are of granite weathered into residual loamy soils very subject to accelerated erosion.

Forests formerly covered large areas, as evidenced by a record dated in 1557 in the gazetteer of Hsing Hsien issued in 1763, which states that before the time of Chia-ching (1522–1566) mountain forests were flourishing and dense in the drainage basin of the Wei-fen River, which rises to the east in Lan Hsien District and flows with several tributaries through Hsing Hsien. In the Fang-shan District considerable areas are still forested, as found and studied by the senior author in 1925. Remnants of the original forest cover lie between the 6,000 and 8,500 foot contours on Kuan-ti Shan. The largest tract consisted of a dense stand of poplar (*Populus*, sp.) and birch (*Betulus*, sp.) which apparently succeeded a coniferous forest entirely cut off at some time in the past. At similar elevations forest stands of pure larch (*Larix dahurica*) were found and mixed stands of larch and spruce.

In Fang Shan District observations showed that the loess cover is cultivated in every locality and on every slope where a man can keep his footing. Above 6,000 feet possible farming land is left to forest not because of low temperatures, but because of the ravages of wild boar on root and other crops. Cutting of the forest in a small way has apparently been carried on for a long period of time, but except in rare instances the soil has not been cleared and cultivated. It is significant that in the forest areas studied no soil erosion was going on, that the water of streams was clear at all times, even after the most violent rains, while under observation from July 26 to August 19 of 1925, when stream flow was being measured. Stream-flow changed little dur-

ing and following these heavy thunderstorm rains; the flow contained bits of humus material in suspension which scarcely discolored the water, but mottled it with blackish particles. Filtering the water following storms gave negative results for silt. Despite the heavy rains that fall in this region (60.3 mm, or 2.37 inches in eleven hours, 40.7 mm, or 1.60 inches, in 10 hours, and 12.5 mm, or 0.5 inches, in one quarter hour were observed), soil erosion is lacking and stream-flow is well regulated (4.8 inches in twenty-four hours was the greatest observed rise in level); whereas in the Tung Chai area such rains on cultivated slopes produced raging torrents, which tore soil and rock out of flanks of mountain sides and carried such debris headlong down water courses as we observed during rainy seasons of 1924 and 1925 and reported elsewhere.[27]

Historical records indicate that such accelerated erosion is of long standing. The gazetteer of Hsing Hsien already cited says: Now (1557) (in the drainage area of the Wei-fen River), the opening up of virgin soil by cultivation is daily extended, and the peaks and slopes are all bared of trees and other covering. Of Lan District in particular, which contains the upper part of this drainage area, its gazetteer dated in 1730 states that even the good fields are eroded by annual heavy rains till they are all cut into watercourses and gullies, leaving an inch of earth difficult to cultivate.

This gazetteer also reports 21,819.62 acres (1,442 ch'ing 14.3 mou) of land in default for grain tax of 6,542 taels, found by investigation to be waste land with no discoverable owners or slopes seriously eroded by water. In 1657 (fourteenth year of Shun-chih) the second month the Shansi governor secured remission by edict of taxes on 1,783 acres (117 ch'ing 85 mou) of deserted land, which had been injured and rendered useless, and in the eighth month of the same year exemption for 18,185 acres (1,201 ch'ing 92.35 mou) of additional deserted land.

That the connection between forest destruction, cultivation of the land and erosion and destructive floods was not unknown to the Chinese nearly four centuries ago is made clear by a passage in the gazetteer of Hsing District, dated in 1557, which says:

> The south side of the city of Hsing Hsien is a few hundred feet from the Wei-fen River, which rises in the mountains of Lan District thirty miles away and has a number of tributaries. Before the time of Chia-ching (1522–1566) mountain forests were flourishing and dense, and although there were heavy rains, still they largely soaked in and were impeded (in runoff), and the river was not a plague. Now the opening up of virgin soil by cultivation is daily extended, and the peaks and slopes are all bared of trees and other covering. Every summer and autumn the water rushes down steep slopes without the slightest obstruction or storage. Therefore its force becomes more angry in its rapid flow, so that the dyke and bank are made to fall in ruins and people's dwellings and the enclosing wall of the South Gate are completely washed away. People in the east and west enclosures have also moved out to avoid calamity.

The walls were repaired in 1555–1556, but in that year or the next the river dyke collapsed to the great danger of the city, and in 1557 Wang Wan called a conference on the matter. Again in 1822 (the second year of Tao-kuang) the river suddenly overflowed after soaking rains, damaged the southeastern corner of the city, destroyed several hundred feet of the city wall and swept away several hundred dwellings (chien). Of the three streets of the East Suburb only one was left; and as to the earth wall and the lane, even their former location could not be made out. The city wall was rebuilt with the aid of 1,000 ounces of silver granted by the Emperor.

Chinese writers in this area report that differences in the use of land have resulted in great differences in regimen of stream-flow, which is regular in forested areas but becomes irregular and destructive where forests have been removed and soil is cultivated and eroded. In the

[27] Part I. p. 400 *f*.

latter case damage to soils leading to their abandonment for cultivation is recorded as an additional result of unleashing of forces of erosion in mountainous regions. K'o-lan Department, lying north of Hsing and Lan Districts and west of Tung Chai, shows similar conditions to these.

The record of land taxation in its gazetteer (1881) shows taxes remitted for over 19,200 acres of land injured and deserted, being more than half the total on the tax list, in the years 1647, 1653 and 1853. Meantime land amounting to 18,626 acres had been newly brought under cultivation by 1728. New land in cultivation had been substituted for most of the abandoned fields.

The record of Yung-ning Department, adjoining Fang-shan District on the south, in gazetteers of 1703 and 1881 is similar to that of Hsing District, with remnants of forest and destructive floods, first mentioned in the Hung-chih period (1488–1505).

The District of T'ai-yuan, a few miles south of the present capital of the Province, lies mostly in the plain of the Fen River, with a steep mountainous area on the west. Here as elsewhere in Shansi the rainfall occurs as heavy thunderstorm downpours in the summer. The soils are alluvial in the plain, having been derived from erosion of the loess at the lower elevations and of residual soils of slopes formerly forested but cleared and cultivated until abandoned.

There is evidence in gazetteers of forests on mountains to the west and southwest of the city of T'ai-yuan Hsien within a few miles of the river. The plain has long been cultivated, in part under irrigation. Records contained in the gazetteer issued in 1826 include accounts of numerous destructive floods beginning in the thirteenth century A.D. These floods through the centuries have entered the city of T'ai-yuan Hsien, silted up and destroyed buildings, carried away dykes and silted up canals for irrigation and the city moat. A stone dyke built in Ming times (Cheng-te period 1506–1521) and repaired in 1528 (the seventh year of Chia-ching) was breached and partly washed away in the first years of Ch'ien-lung (1736–1795), the water forming three sand rivers up to the east and north suburbs of the city. Another breach was produced in 1752 and 1753 (the seventeenth and eighteenth years of Ch'ien-lung) with still greater injury to the west and south suburbs and to neighboring fields and houses. In 1287 (the twenty-fourth year of Yuan-Shih-tsu Chih-yuan) the river overflowed and damaged crops. In 1501 (fourteenth year of Hsiao-tsung Hung-chih) the

DENSE POPLAR STANDS

WHICH FURNISH EXCELLENT MATERIAL FOR MATCH STOCK. A MATCH COMPANY ESTABLISHED ITS HEADQUARTERS IN THIS FANG SHAN AREA OF SHANSI FOR THE EXPLOITATION OF LARGE AREAS OF THIS TYPE OF FOREST.

GENERAL VIEW OF CUTTING IN A FOREST OF LARCH, FANG SHAN AREA
SHOWING THE TIMBERS PREPARED READY FOR PACKING OUT ON MULE BACK TO THE VALLEY.

water of the Fen rose more than forty feet. Of the villages and hamlets along the river banks the houses and growing grain were carried away or submerged almost altogether; and a great famine followed, we are told. Again in "the sixteenth year of Mu-tsung Lung-ch'ing" (1582? perhaps an error for sixth, 1572) a great famine is reported when the Fen River overflowed its banks, carrying away and inundating growing grain on both east and west sides. In 1683 (twenty-second year of K'ang-hsi) floods in autumn carried away and inundated almost completely the crops of standing grain.

In 1725 (the third year of Yung-cheng) flood waters from the Fen were four or five feet deep over level land, crops were swept away or inundated and dwellings in certain named villages collapsed in ruins. In 1748 (the thirteenth year of Ch'ien-lung) an overflow of the Fen when wheat was ripe emptied all the heads in one evening. In 1768 (the thirty-third year) with heavy rain the Fen overflowed and a torrent from Wind Valley (Feng-yü) ruined over 400 feet of the city wall. In 1775 (the fortieth year) water from Wind Valley swept away and inundated several villages southwest of the city, both fields and dwellings, and inundated Yin-Kung Shrine. And so the tragic account goes on for district after district of Shansi.

The gazetteer of Ch'ing-yuan suburban district (now Ch'ing-yuan Hsien, southwest of T'ai-yuan Hsien), for 1882 also shows forest remnants, as temple and monastery forests, and records many damaging floods of the Fen and other rivers, also two shifts in the bed of the Fen River in 1870 and 1872. Blocking of canals with silt is frequently reported in the records.

Hsu-kou District east of Ch'ing-yuan across the Fen River lies in the plain. Its gazetteer of 1712 records no trees but willow plantings around moat and dyke. Many destructive floods over the plain are reported, along with stoppage of canals with silt and covering of land with mud and sand, and the drying up of an irrigating canal in spring and summer. Continuing destructive floods are reported in the gazetteer of 1881. This work also reports the entire disappearance of groves of willow trees formerly

growing about the earthen altars dedicated to spirits of the land and grain and to those of woods, cloud, thunder and rain.

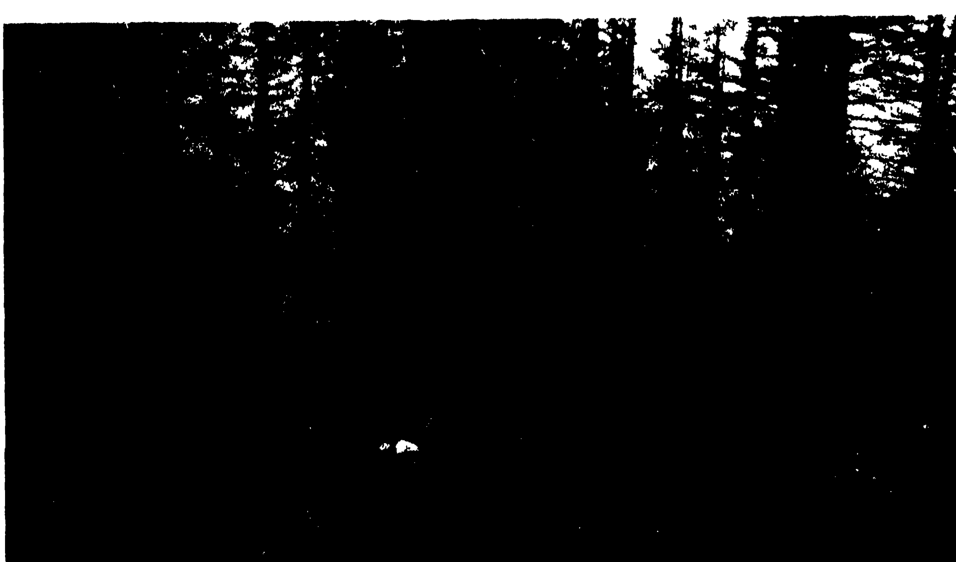
In this area we find deforestation, combined with extensive damage to agricultural land, to irrigation canals and to other works of man by torrential floods originating in deforested mountains.

T'ai-ku District lies a little to the east of the Fen River, its western part in the plain and its eastern part hilly and mountainous. Rainfall occurs in great part as thunderstorm downpours, with occasional gentle rains. Soils are made up chiefly of a deep mantle of loess which is very fertile if watered with rains, but also very susceptible to rapid gully erosion when cultivated on slopes without terracing.

The gazetteer of T'ai-ku District published in 1855 records past deforestation of various mountains and hills. Regarding a mountain called Pine Range (Sung Ling) ten miles southeast of the city it quotes the Wang gazetteer (1739) as saying: "The mountain is high, pines flourishing; in the morning clouds rise like towers; one of the ten (famous) views. Afterwards it was sought out with axe and hatchet; the forest of pines disappeared and the mountain was left bare; the clouds also had no place to rest on. Now only the empty name remains." (See also poem in 8/21 b f.). Of the Dragon Hills (Lung Kang) five li NE. of the city, it says: "One of the ten famous views. In late Ming and early Ch'ing dynasty times thick stands of pine and cedar grew on the hills. Cutting for timber went on rapidly, and the hills were gradually denuded of trees and herbage, and now nothing is left on the small hills, and all are bare of trees."

Regarding the behavior of streams and rivers it quotes another earlier gazetteer (1795):

> Irrigation in the southeast is easy, in the northwest more difficult, for using water of the plain is easier, but waters from the mountains harder; because great rivers, although they may keep their names, are as blotted out in fall and winter, and in summer when it rains mountain torrents rise suddenly; if there is nothing to withstand the wild waters, they overflow the land



VIEW OF LARCH FOREST WITH CUTTING IN PROGRESS

FANG SHAN AREA OF THE PROVINCE OF SHANSI. THE LARCH OCCURS AS PURE STANDS IN GROUPS. SPRUCE AND BIRCH ARE INTERMIXED IN THE DAMPER AREAS.

in all directions; and if there are no dykes to lead and collect the flood waters, they quickly cut gullies and go straight on, and are lost for irrigation. Therefore the difficulty of profitable use of water is nowhere greater than in Shansi, both as to high and low water.

The adjoining district of Ch'i Hsien has somewhat similar records, both of forest remnants on certain mountains and of destructive floods from 1544 on. The same is true of Wen-shui District, to the west across the Fen River, in which the first flood reported was in 1491, and shiftings in the course of rivers repeatedly occur. There in 1657, 2,812.67 acres (185 ch'ing 89.982 mou) of land were exempted from taxation because carried away by a river or occupied by water. Similar records come from Fen-yang District (Fenchowfu) to the south of this and from P'ing-yao District next southeast across the Fen. Farther south along the Fen River we find similar records in gazetteers of the Districts of Chieh-hsiu, Ling-shih, Hung-tung, Lin-Fen and Chi-shan.

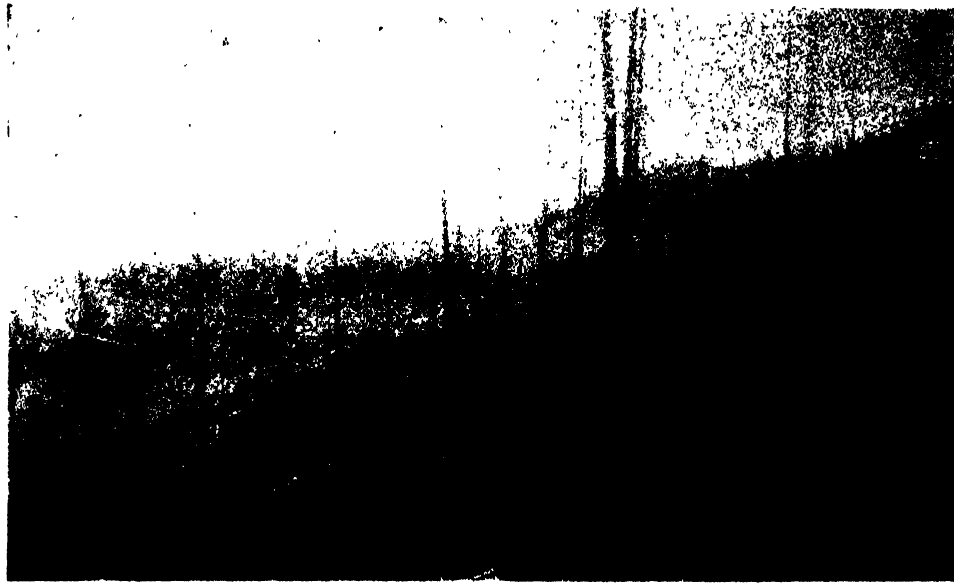
The District of Ch'in-yuan lies near the headwaters of the Ch'in River, which drains a large portion of the dissected highland of southeastern Shansi. The mountain massif reaches altitudes of 7,000 feet in the highest points; the general elevation of the tops of the ridges varies between 5,000 and 6,000 feet. The valleys are generally steep-walled, and the face of the landscape is conspicuously dissected. The floors of the main drainage system in the upper part of the watershed are 500 to 1,000 feet below the general plain of the higher ridges. A high ridge along the west side of the district separates this drainage from that of the Fen River.

The rainfall comes mainly as convectional summer thunderstorms, with occasional gentle rains.

The soils in this district are chiefly residual, being derived from calcareous formations bearing coal seams and hard shales. Within temple forests soils with normal profiles mantle the country rock,

DETAILED CUTTING, SHOWING HOW WASTE TIMBER IS LEFT IN TREE TOPS

SUCH KNOTTY MATERIAL DOES NOT PAY FOR TRANSPORTATION BY PACK MULES. MUCH WASTE OF TIMBER OCCURS HERE IN THE FANG SHAN AREA, IN SPITE OF THE GREAT NEED OF TIMBER IN CHINA, PARTIALLY RESULTING FROM THIS WASTE.



A CUTTING OVERRUN BY A SLASH FIRE IN THE FANG SHAN AREA
NOTE HIGH STUMPS THAT ARE SERIOUS WASTAGE OF TIMBER. LABOR AND MANAGEMENT PROBLEMS WERE RESPONSIBLE FOR HIGH STUMPS IN THIS CASE.

but the soil profile is generally eroded away to parent material in old cultivated areas. Soil accumulates in benches behind roughly horizontal bands of vegetation, and is there still cultivated in much reduced area.

Small tracts of forests were examined by the senior author in 1925 and are mentioned in gazetteers of Ch'in-yuan District (1730, 1881). These have been preserved by near-by villages, sometimes acting in concert. The region is generally cultivated, except for the scattered forests, but as much as 40 per cent. of the region is now in barren slopes, which generally show evidences of former cultivation. Where abandoned, the slopes are coming back to a tree cover, but very slowly, for grazing by sheep and goats tends to keep the vegetation down.

In the northern part of the district, at T'sung-tzu Yü, the senior author made a study of a forest about sixteen acres in area which had been protected and managed by the village, whereas surrounding areas had been cleared and cultivated and were seriously eroded. This forest of pine (*Pinus Massoniana*) lies between the contours of 4,500 and 4,800 feet; the forest floor is covered with a flourishing understory of shrubs. Doubtless this growth owes its preservation from fuel gatherers to easily accessible seams of coal in the surrounding region.

Records of runoff were made for duplicate plots in the forest and on a homologous but denuded slope near-by, in twenty-three storms covering a period of eighteen days and totaling a fall of 12.1 inches (307.5 mm) of rain. In the forest plots the percentage of runoff for the total of twenty-three storms was .126 per cent., where the greatest runoff coefficient for a single storm was 0.284 per cent. From plots in fields denuded by erosion, the average runoff coefficient of total rainfall was 7.2 per cent. and the greatest measured for a single storm was 19.85 per cent. A most significant finding was that no erosion took place in the forested

LOADING HEWN TIMBERS

ON A MULE TO BE TRANSPORTED FROM THE FANG SHAN AREA DOWN SLOPE TO THE STREAM FOR FLOATING TO THE VALLEY. THE MOUNTAINS IN THE MIDDLE FOREGROUND HAVE BEEN DEFORESTED.

area, in sharp contrast to that on the denuded area, where erosion was heavy and during two storms excessive silt and detritus so clogged the instruments that the records were lost on these two occasions, when runoff and erosion were greatest of all storms of the rainy season.

The gazetteers also give records of floods in this district. That of 1730 tells that in 1513 (eighth year of Cheng-te) floods carried away and inundated more than a thousand ch'ing (15,130 acres) of agricultural land. Several hundred ch'ing of fields are recorded as again flooded by the Ch'in River in 1591 (Wan-li nineteenth year). In 1651, 1652 and 1653 there were floods which ruined more than 687 ch'ing (10,394 acres) of agricultural land. The supplementary gazetteer of 1881 tells of the land of a whole village being deserted because of calamity after calamity from floods.

In 1877 flood damages were heavy, after which taxes on the land of this village were revoked in perpetuity. One piece of school land is recorded as buried with sand and two others as washed away by floods. The gazetteer of 1730 records the exemption from taxation in 1657 of 10,417 acres (688 ch'ing 48 mou) of land damaged or destroyed and then deserted. Remaining crop land was only 30,652 acres (2,025 ch'ing 91 mou). In 1729 and 1730 (seventh and eighth years of Yung-cheng) 461.6 acres (30 ch'ing 50.9 mou) of land were recorded as newly brought under cultivation.

Extensive remnants of early forests are left on Mien-shan or Mien Mountain partly in this district and partly in the districts of Chieh-hsiu and Ling-shih. One area of ancient forest is carefully preserved by eighteen villages, which together control the cutting of trees. A temple stands in this communal forest, which also contains 4,000 or more of a rare species of white-barked pine (*Pinus Bungeana*).[28]

This area shows most of the facts shown in other areas already studied. Partial protection of forests, in this case mainly by villages, sometimes acting in a group, has prevented excessive erosion; but where sloping lands were cleared and cultivated, they have been damaged or ruined by erosion and abandoned for agriculture. Restoration of forest cover on such areas is delayed by grazing of sheep and goats; and destructive floods occur in streams that drain denuded areas.

Farther to the southeast near the corner of the province, Kao-p'ing District

[28] *Cf.* H. Smith, "Preliminary Report on Botanical Investigation in South and Central Shansi," *China Journal*, 3: 505–507. 1925.

shows a record similar, but with forests more a thing of the past and with floods more prominent in its history. As one writer in the gazetteer of 1880 put it: "Formerly able men vied with one another in profit from irrigation, but now . . . silt daily collects in canals and the waters are reduced . . . crops are damaged by excessive water in floods. Water brings ruin instead of profit."

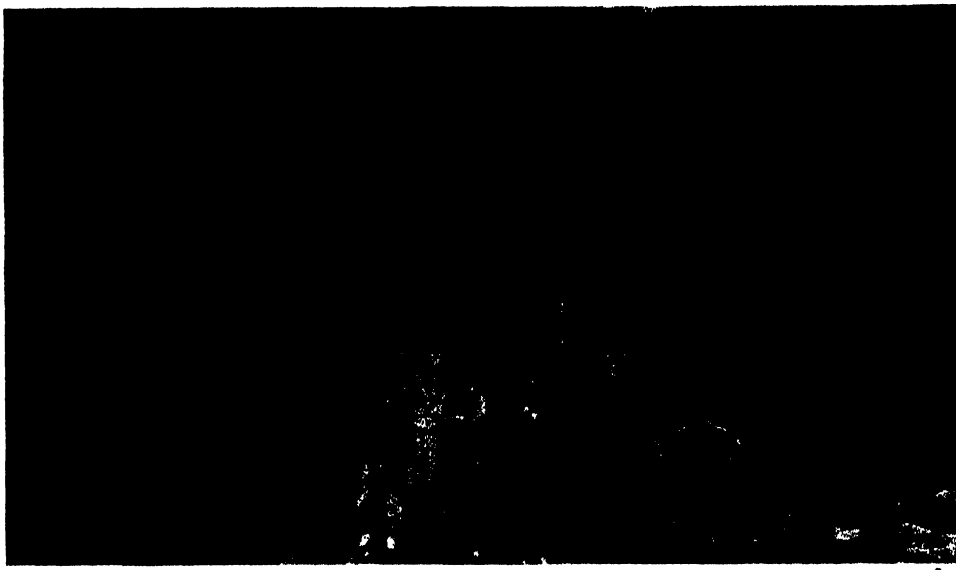
Such in brief is the record in gazetteers and in the land of how deforestation, cultivation and erosion with consequent flooding and silting, have taken place in the Province of Shansi. This record covers only a part of the long history of China, and belongs to the "dark period" according to some historians.

Conservation in Chinese History

The history of the treatment of forests in China before the Republic has been classified into three periods by Teng Shu-chun[29]: the Ancient Period, from earliest time to about 1100 B.C., the Golden Period from 1100 B.C. to 250 B.C., and the Dark Period from 250 B.C. to A.D. 1911. In the Golden Period rapid progress was made in steps toward conservation of land and forests. These measures suggest those now being applied in the United States. More than 2,000 years ago in China land was classified as to its best use, and regulations were set up for its distribution to and cultivation by the population. Commissions of mountain forests and of swamps were set up. Policing of foothill forests and of rivers and streams was provided for. The Commission for Mountain Forests was put in control of mountainous lands and the forests and set up rules and regulations for protecting and harvesting them. Cutting of timber was limited to certain periods of the year. And more surprising still, if one is surprised at the genius of the Chinese people, wild-life regulations were set up for the swamps and game and wild fowl. In short, we have in this remarkable era, when the classics of China were written by the sages, the principles of

[29] Teng Shu-chun, M. F. "The early History of Forestry in China," *Jour. For.*, 25: 564 *f*. Washington, 1927.

RAFTING TIMBER DOWN A STREAM IN THE FANG SHAN AREA
THE LOGS ARE MADE INTO GREAT SNAKE RAFTS WHICH ARE SKILFULLY GUIDED BY BOLD RIVERMEN DOWN THE SHALLOW WATER OF MOUNTAIN STREAMS TO THE VALLEY.



VIEW OF HEADQUARTERS OF A MATCH COMPANY
CONSTRUCTED TO HARVEST TIMBER OF A GREAT TEMPLE FOREST OF SOME TWENTY SQUARE MILES IN THE FANG SHAN MOUNTAINS. THE FOREST IS SPRUCE AND LARCH ON THE SLOPES, AND BIRCH AND POPLAR IN THE MOIST VALLEYS.

conservation set forth in remarkably clear outline, and apparently upheld for centuries with governmental regulations.

But these wise measures seem to have been relaxed with the decline of the Chow Dynasty and the growing strength of the feudal states when intense rivalry and conflict spread throughout the country. Warfare nullified regulations and fostered exploitation of forests and lands.[30]

Then followed what Teng has called the Dark Period of about 2,000 years. This period was ushered in by Ch'in Shih-Huang, whose great program of construction would have been possible only with abundant timber supplies, and is believed to have been the principal cause for deforesting extensive areas that were never allowed to grow up to forest again. Only in the temple groves and forests do we find remnants of the original forests of the Golden Period, to which the senior author has called attention. These remnant forests protected by temples are instructive in giving highly useful information, as samples of the original condition of soil and forests throughout most of China, as the sort of forest growth that the present climate will support, and as areas having the normal rate of geologic erosion when compared with erosion accelerated by clearing and cultivation of slopes, and finally as the goals of the new conservation program that may reasonably be achieved. In these respects "temple forests" have the highest scientific and practical interest in the reconstruction and conservation program of China. Our account of what has happened in the Province of Shansi is indicative of what went on throughout the greater part of China during the latter part of the Dark Period.

With overthrow of the reactionary Manchu Dynasty and establishment of

[30] Teng, S. C. *Id.*, p. 567. So also Chang, F. Y. "Historical Sketch of Chinese Forestry," *Jour. of the Agricultural Association of China*, No. 77, June, 1930, pp. 4 *f.* (in Chinese).

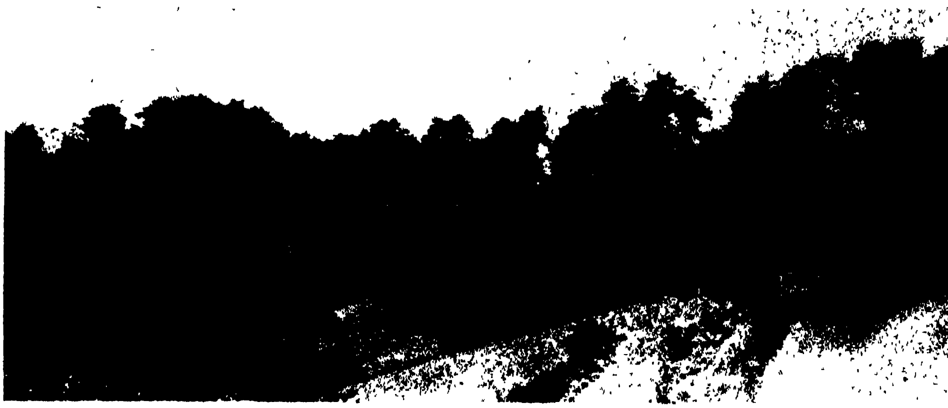
the Republic in 1912, there was begun a new period, which may be called the Period of Reconstruction. To its aid came modern pure and applied sciences of agriculture, forestry and engineering. In that year the Ministry of Agriculture and Forestry was established and forest nurseries were started throughout China. In 1914, this Ministry was combined with the Ministry of Industry and Commerce to form the Ministry of Agriculture and Commerce which has finally been changed to the Ministry of Agriculture and Forestry. Many Chinese students were sent to the United States, some of whom have been trained in fundamental and applied sciences of agriculture and forestry. But still more Chinese students were trained in these fields in American supported universities and colleges in China, and in national universities, and have become more and more influential in the Chinese Government. These well-trained men and women furnish the aims and major drive of the reconstruction movement in China.

Movements for Conservation in the Old and New Worlds

Poetic justice has worked its wondrous ways again in mutual aid by China and the United States in developing conservation in the two countries. So old and so new is the experience of these countries in use of their respective lands that such community of interest may at first seem to be remarkable. From China the United States, as we have seen, got much of its inspiration for conservation of forests; in turn China got from America a new impetus to principles of conservation that had been enunciated in China during the "Golden Period," more than twenty-two centuries ago. From America, China got her start in scientific forestry, although the senior author found in isolated parts of China, forestry practiced in greater detail than he had ever seen in Germany. It was under the late Colonel George P. Ahern, as director of the Bureau of Forestry of the Philippines in 1911 and later years that the movement for training Chinese students

SLOPES CLEARED FOR CULTIVATION AND LARGELY ABANDONED

IN THE CH'IN YUAN DISTRICT, SHANSI, WITH ONE SLOPE IN PROTECTED FOREST. SOIL EROSION IS HERE WAGING A WINNING FIGHT WITH CULTIVATION. THE BENCHING OF SOIL AGAINST HORIZONTAL STRIPS OF PERENNIAL GROWTH STILL PROVIDES SITES FOR CULTIVATED FIELDS.



RIDGE WITH VILLAGE FOREST ON THE FAR SIDE, CH'IN-YUAN DISTRICT
THE FIELD IS CULTIVATED TO THE VERY SUMMIT, BUT BECAUSE OF GULLIES WASHED IN THE SOIL COULD BE CULTIVATED CONTINUOUSLY NO LONGER THAN TEN YEARS.

at the Forest School in Manila began. Later a School of Forestry was established in the College of Agriculture and Forestry of the University of Nanking by Joseph Baillie, followed by Dean J. H. Reisner and then by Dean K. S. Kuo,* and other able Chinese leaders. Moreover, many Chinese leaders in forestry and conservation were trained in the United States, and became "American Returned Students." Of these, Ngan Han, trained at the Forestry School of Michigan, was the first director of forestry for China; and D. Y. Lin, a graduate of Massachusetts Agricultural College and later of the Yale Forest School, as professor of forestry at Nanking gave a series of lectures throughout China on conservation with special reference to forests, and created a national interest that has persisted and grown to this day but with setbacks due to internal and foreign wars, and has been a major influence in the Government for conservation and flood control. Many others too numerous to mention here have made important contributions to forest and soil conservation. Despite handicaps, remarkable progress in conservation has been made under the leadership of the Generalissimo Chiang Kai-shek in the national reconstruction program, the progress of which has amazed foreign observers, and carried on despite deep invasion of a ruthless foreign army.

* Now director of the National Bureau of Research.

The movement in the United States for the conservation of soils has grown out of soil surveys and experimental studies of soil erosion. About thirty years ago, Dr. H. H. Bennett, chief of the Soil Conservation Service, then a soil surveyor, challenged the method then in use of giving a new soil series name to a subsoil eroded bare of its top soil, of the same soil series.[31] This early work established a scientific basis for recognition of soil erosion in soil surveys. It was not, however, until experimental studies by Duley and Miller,[32] Bartel,[33] the senior author,[34] Bennett and Chapline,[35] Dick-

[31] Bennett, H. H. Soils of the United States. *U.S.D.A. Bul.* 96. 1913.

[32] Duley, F. L. and Miller, M. F. Erosion and Surface Runoff under Different Soil Conditions. *Mo. Agr. Expt. Sta. Research Bul.* 63. 1923.

[33] Bartel, F. O. First Progress Report on Soil Erosion Experiments. North Carolina Expt. Sta. Farm, Raleigh, U. S. Bureau of Public Roads, Div. Agr. Eng. 1925. Third Progress Report, 1928 (Mimeog.).

[34] Lowdermilk, W. C. Factors Influencing the Surface Runoff of Rain Waters. *Proc. 3d Pan-Pacific Science Congress*, Tokyo, 1926. Further

son,[36,37] Conner and Scoates,[37] Phillips,[38] and Bennett,[39] with numerous succeeding studies, made comparative measurements of the losses of rainfall by immediate runoff and of the losses of soil in this runoff that it was possible to compute how rapidly top soils were being washed away. These measurements indicated for the first time how soils deteriorate and are damaged through soil erosion far more rapidly than through cropping long before the spectacular gully stage sets in. Such experimental measurements disclosed how rapidly soil is impoverished and destroyed by erosion, especially on sloping lands under heavy rainstorms, when no measures of erosion control are used. Here, for the first time, was a factual basis for a study of the enormity of damage to land resources by soil erosion under unwise land use. These records of erosion wastage and loss aroused general interest in the problem of conservation on the part of business people, bankers, agriculturists and statesmen as well as of farmers who suffered first hand the losses from soil erosion.

Out of this better understanding of soil erosion and its menace to national welfare, there was launched the nationwide movement for soil conservation in 1933 by means of demonstration projects located throughout badly eroding areas of the country by the Soil Erosion Ser-

Studies of Factors Affecting Surficial Runoff and Erosion. *Proc. Internat. Cong. of Forestry Expt. Stations*, Stockholm. 1929.

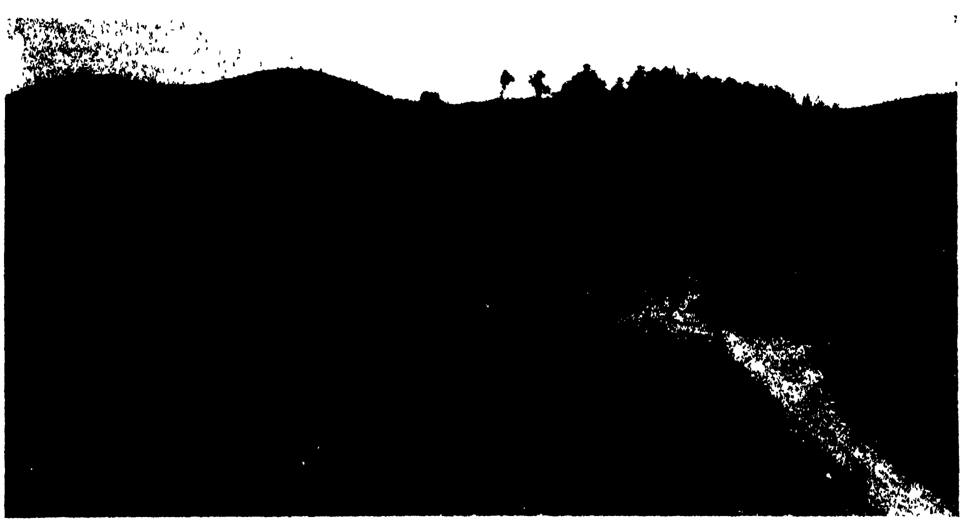
[35] Bennett, H. H. and Chapline, W. R. Soil Erosion a National Menace. *U.S.D.A.* Circular No. 33. 1928.

[36] Dickson, R. E. Results and Significance of the Spur (Texas)) Runoff and Erosion Experiments. *Jour. Am. Soc. Agron.*, 21: 415–422. 1929.

[37] Conner, A. B., R. E. Dickson and D. Scoates. Factors Influencing Run-off and Soil Erosion. *Bull. No. 411.* Texas Agr. Exp. Station. College Station, Texas. 1930.

[38] Phillips, Samuel W. Soil Erosion Work of the Bureau of Chemistry and Soils at Guthrie, Oklahoma. 2d Southwest Soil and Water Conservation Conference, 1931, 40–45. Ramser, R. E. Results of Experiments on Erosion Control on Guthrie Soil Erosion Experimental Farm. *Id.*, 46–53.

[39] Bennett, H. H. Dynamic Action of Rains in Relation to Erosion in the Humid Region. *Trans. Am. Geophysical Union*, 15th Ann. Meeting, 1934: 474–488.



FORESTED AND DENUDED SLOPES IN CH'IN-YUAN DISTRICT, SHANSI

AT THE RIGHT IS NATURAL FOREST PROTECTED BY THE VILLAGE OF TS'UNG-TZU YÜ. THIS FOREST AND THE SLOPE AT THE LEFT OF THE PICTURE WERE USED BY THE SENIOR AUTHOR FOR RUNOFF PLOT STUDIES OF COMPARATIVE RUNOFF.

vice as an emergency organization. The practical and far-reaching significance of this work gave rise to the passage of the Soil Conservation Act of 1935, passed without a dissenting vote in the House of Representatives and the Senate, that set up the Soil Conservation Service in the Department of Agriculture. This act marks the beginning of a new era in the relation of the American people to their land resources. For the preamble of this act states the purpose of the law in these words:

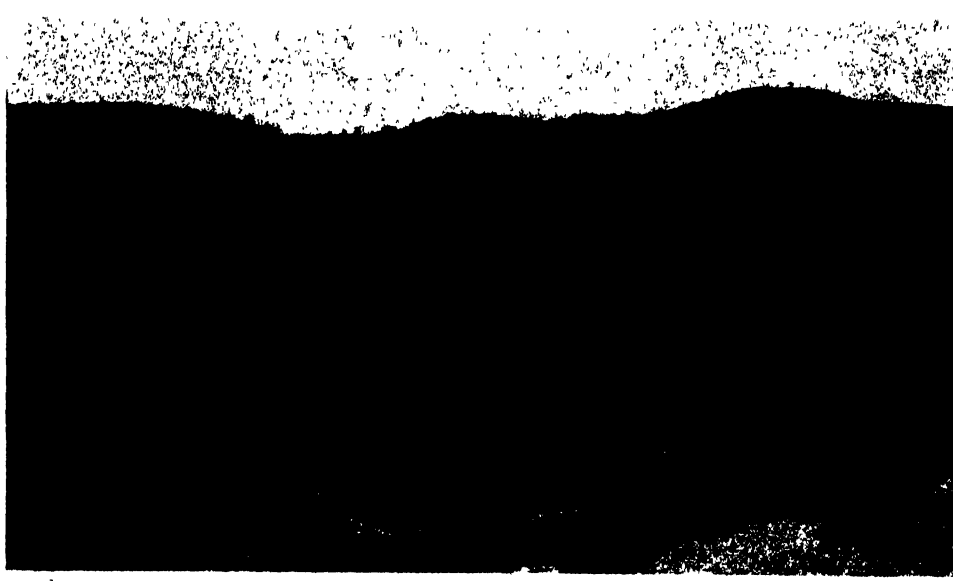
> Be it enacted by the Senate and House of Representatives of the United States of America in Congress Assembled, That it is hereby recognized that the wastage of soil and moisture resources on farm, grazing, and forest lands of the Nation, resulting from soil erosion, is a menace to the national welfare and that it is hereby declared to be the policy of Congress to provide permanently for the control and prevention of soil erosion and thereby to preserve natural resources, control floods, prevent impairment of reservoirs, and maintain the navigability of rivers and harbors, protect public health, public lands and relieve unemployment, and the Secretary of Agriculture, from now on, shall coordinate and direct all activities with relation to soil erosion. . . .

Modern methods of soil conservation in use in the United States by the Soil Conservation Service are developed out of an evaluation of past experience and current research. But in China, past experience has taught the Chinese farmer through centuries of hit-or-miss trial and error a few fundamentals in land use. The Chinese have found that lands must be nearly level if they are to be saved for use from generation to generation. Either they must be naturally so as in alluvial and delta plains, or they must be made so by terracing. The bench terrace, which reduces gradients of natural slopes for cultivation, has been successful where applied and maintained. A low gradient necessary in conserving soil also conserves rain waters in the soil for crop growth. Moreover, cooperation in concerted effort under a unified direction is also necessary to success in efforts for the conservation of soil and water. In China's long past, when such direction was lacking, conservation failed and lands wasted away. A single farmer is often helpless in the face of soil erosion

INTERIOR OF VILLAGE FOREST AT TS'UNG-TZU YÜ, CH'IN-YUAN DISTRICT
SHOWING A RATHER THIN STAND OF PINE AND A DENSE NATIVE SHRUB COVER. THE LATTER WAS THE MOST EFFECTIVE AGENT IN PREVENTING EROSION AND IN MAKING CONDITIONS THAT RETAIN WATER.

or of a flood, without the cooperation of others on the slopes above. This the Chinese had discovered, but had not been able to do much about it. With a background of geology and hydrology and soil science, conservation of soil and water in the United States comes to be recognized as a physiographic problem, and is best handled on a basis of drainage areas.

Out of such findings of the past and research of the present has come a national movement for conserving land, with its moisture and included plant foods. The program of this movement prescribes as a general principle contour farming supported by all necessary measures to increase the intake of rain waters by the soil under cultivation and grazing, to control unabsorbed storm runoff and lead it harmlessly down to natural drainage channels, and to reclaim badly eroding and eroded areas with mantles of vegetation. Supporting measures include contour strip cropping, broad base terraces, vegetal covers fully maintained, the use of crop litter or stubble mulch on soil surfaces, acting in the same way as forest litter to increase infiltration of rain and reduce erosion, the improvement of soil structure to increase its capacity to take in rain waters, supported by appropriate soil amendments, grassed waterways to lead unabsorbed waters to natural drainage channels, and gully control. Thirty-one and a half million acres of land in the United States have already been treated under cooperative farm plans worked out by field personnel of the Soil Conservation Service. More than ten times this area of good land is eroding and is urgently in need of treatment. The chief hazard to the land, both in China and America, is the neglect of known methods and lack of making adjustments in the use of land by appropriate experimental studies as rapidly as pressure of population impinges upon crop-growing capacity of the land. Demands upon land vary with passage of time and economic circumstance. Unless measures for conserving soils under such



GENERAL VIEW OF DENUDED SLOPE, CH'IN-YUAN DISTRICT, SHANSI

HOMOLOGOUS IN GRADIENT, ASPECT, ELEVATION AND SUBSOIL WITH FOREST PLOT 500 FEET AWAY. WHEREVER POSSIBLE THE SLOPE IS STILL CULTIVATED. ONCE THE ENTIRE SLOPE WAS CULTIVATED.

changes are varied to meet new hazards to the physical integrity of the resource, much of the national heritage of the land is irreparably damaged or destroyed before revised measures of improved land use can be found out by study or tardy experience. Trends in land use must be proved and studied with foresight to have ways and means already worked out to meet current needs for necessary crops with conservation of the national heritage in the soil.

Summary

Our survey of twenty-seven counties and prefectures in the Province of Shansi of China is already summarized with some typical excerpts translated from the Chinese, lest the paper be too long. As a whole these accounts are striking records of an early appreciation of needs and urgency of conservation, sound principles of which were enunciated more than twenty-two centuries ago. In some isolated parts of China, the senior author found forestry practiced in greater detail than he ever saw in Germany. Such areas are obviously remnants of larger managed areas in former times. The terracing of slopes in some parts of China, particularly in regions of the great loessial soil mantle, also represents practical and complete conservation of soils. Nevertheless repeated efforts at conservation of forests and soils in the Province of Shansi broke down for one reason or another. Among the more important causes were interruptions of orderly government, and the exploitation of areas, chiefly under a foreign dynasty of nomadic origin, the Manchus.

Mountainous regions of Shansi that were originally covered with dense forests were cut clear of timber leaving the region a place of desolation. Because of this, representatives of the Emperor became concerned and secured an Imperial Edict against this wastage of forests and lands. Restriction of such exploitation restored a forest cover in Wu-t'ai Shan. Armand David has suggested that cultivation of high slopes in North China followed the introduction of crops from the New World, corn and potatoes, adapted to higher altitudes than those previously cultivated. Introduction of such crops, of which we noticed evidence for this region, would doubtless promote such cultivation. From about 1656 on, the cultivation line was pushed up slopes of this sacred mountain region to bring on a period of devastating erosion from which the region has never recovered. Devastating erosion in the mountains brought about torrential floods charged with debris of soil and rock that wrought great damage to farm lands of the alluvial plains by flooding and overwash of detritus.

The recent reconstruction movement, with the benefit of principles and experience from both China and America, promises great things for the land and people of China when the invader has been driven out and peace makes possible undivided attention to the great task of reconstruction. The American people have much to contribute and much to learn from the objects and achievements of reconstruction in China. For these two countries have a unique advantage in producing all their own food supply; they have a like need for safeguarding all resources toward maintaining this advantage. The dreams of wise men of old may in time be realized with science and cooperation in conservation in the Old and New Worlds.

CATTLE RANCHING IN THE TROPICAL RAINFOREST[1]

By Dr. RAYMOND E. CRIST

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There has probably been more highly imaginative writing about the tropical rainforest belt ("jungle" in the vernacular) than about any other climatic region in the world, with the possible exception of the polar regions. In the mind of the middle-latitude public the heavy rainforest is densely populated with fierce man-eating animals, venomous snakes, and noxious insects by the countless million, and many pens have been kept busy giving this public what it wants. Most of the best-sellers about the tropics deal with either the terrors or the romance of that region—or both. Of course, it is hot at low elevations in the tropics, as is to be expected, but it never gets as hot anywhere in the American tropics as it does in the Middle West every summer—in Chicago, Kansas City, St. Louis or Cincinnati, for example. A case of sunstroke in the tropics is as rare as frostbite.

In the tropical rainforest southwest of Lake Maracaibo, Venezuela, there are fairly distinct wet and dry seasons. November, December, and January and May, June, and July are considered the wet months, that is, when the sun is farthest south, and also during its northern sojourn. During these months it rains almost every afternoon. After the rain the sun comes out, and the sensible temperature is even higher than before the shower. There is often a light shower about 4 or 5 o'clock in the morning. There is apt to be a convectional shower in the afternoon any time of the year, even during the dry season. The relative humidity is always high.

Land in the State of Zulia, Venezuela, which includes most of the area tributary to Lake Maracaibo, can not be purchased outright in the usual manner. The state retains control of all subsurface products. One acquires only the surface rights, and the rights to what is produced on the surface. Surface rights are valid only upon continued use of the land; if it is not used for a period of five years, it is considered abandoned, and anyone who wants to can settle on it, provided of course that he works it. This arrangement is very similar to that of the Kamarakoto Indians of the Venezuelan Guayana region, who have no title to land and can not inherit or transmit it. As long as a member of the tribe works his *conuco* he is entitled to all its produce; when he ceases to do so it reverts to the community. Even an unoccupied house belongs to anyone who wishes to occupy it.[2]

It was in the region of tropical rainforest southwest of Lake Maracaibo that Mr. McRae, an American engineer with a little capital and all his time to invest, decided to buy a cattle ranch. He bought the surface rights for 800 acres of pasture land, buildings, and stock on the ranch for 40,000 Bolivares, paying 10,000 down and 5,000 a year. He already has 40,000 B. worth of stock on it. If the worst happened and someone showed up with an old but clear title to the property, an occurrence only too common in Venezuela, the present owner would simply sell all his stock, roll up

[1] The field work on which this article is based was made possible by grants from the John S. Guggenheim Memorial Foundation and the Graduate Research Board of the University of Illinois.

[2] Simpson, G. G., "Los Indios Kamarakotos," *Revista de Fomento*, Año III, Nos. 22–25, p. 544.

A CLEARING IN TROPICAL RAINFOREST

THE BRUSH IS BURNED AS SOON AS IT IS DRY ENOUGH AND CORN IS PLANTED IN THE ASHY SOIL AMONG THE UNBURNED LOGS. AFTER A CROP OR TWO OF CORN, GRASS IS PLANTED AND THE LOGS ROT AWAY. THE PIONEER'S HUT, WITH ITS PLANTAIN PATCH NEARBY, IS IN THE BACKGROUND.

his barbed wire, sell what he could of his house materials and still be ahead of the game financially.

When a man wishes to found a ranch—and this was the case with Mr. McRae—his first task is to find laborers, whom he usually recruits from the ranks of the shifting agriculturalists who have already cut little notches in the forest along the river or, in this case, along the narrow-gauge railroad. He pays them their food while they are clearing the land. Only a few giant trees are left to serve as shade later. Once cut, the great mass of vegetation is allowed to dry and is then set on fire. The land is planted in corn, and grass or plantains are planted between the hills at the same time. When the corn is harvested half of it goes to the man who has cleared the land. The plantains or grass are allowed to grow to maturity. Another crop or two of corn could be and occasionally is grown, but by the end of three years the potash left by the burning has been leached out, and corn doesn't thrive anymore. And the price of corn fluctuates greatly; this year (1941) it is worth less than half what it was worth a year ago. Since plantains are used locally much as potatoes are in the United States, there is always a good sale for them both in the nearby and in the Maracaibo market. They net Mr. McRae some 500 B. a month now from about 45 acres.

One of the difficult problems in the American tropics generally is that of getting sufficient labor. This problem has been aggravated in Venezuela by the fact that thousands of laborers have migrated to the oil fields where wages are high. And the labor law shows little leniency for the entrepreneur. The result has been to put a premium on contract labor. A certain individual agrees to have a given piece of work done within a specified time. If a worker gets hurt on the job it is the worry of the contractor, not of the rancher or the Mayordomo. The former can drop out of sight for a while or start working in another State—not so easy for the rancher. At present two men care for the cattle and hogs. On the average about five are engaged in other tasks, such as clearing new land, cleaning pas-

A WELL-DEVELOPED FIELD OF GRASS

THE LEVEL LINE IN THE MIDDLE GROUND IS FORMED BY THE TOPS OF PLANTAINS BEYOND WHICH SECOND GROWTH TREES CAN BE SEEN IN THE LEFT BACKGROUND. IN THE RIGHT BACKGROUND THERE IS VISIBLE A VIRGIN TROPICAL RAINFOREST.

ture, stretching barbed wire, gathering plantains. They are given 2½ B. a day with food, or four if they board themselves. Warm weather adversely affects the appetite of some people, but not necessarily of men doing hard work even in the heat of the tropics. One man was found who ate four pounds of cheese a day, besides two plates of rolled oats for breakfast, and three roast plantains at each sitting. Fortunately he ate many oranges between meals. It was too expensive an experiment to see how long this could last, and he was discharged at the end of the month.

At the ranch house itself, separated as it is from the virgin forest by wide stretches of cleared land, mosquitoes are rare. The house is not hermetically screened as yet but will be soon. But mosquitoes are very bad in or near the forest where the *conucos*, or kitchen gardens, or homes of the workers are located. Malaria is all too common, as well as diseases and parasites of the intestinal tract—hook worm, amoebic dysentery, etc. No statistics are available, but infant mortality rates are certainly high. The usual diet of the workmen consists of plantains and white cheese. Those who can afford it have a somewhat more varied diet. The Mayordomo, for instance, adds beans, dried fish, meat and noodles to his diet. Fortunately, good water is obtainable at relatively shallow depths (the ranch gets good water at a depth of eight meters) but in many cases wells are too shallow, improper care is taken of sewage, and water gets polluted. A big step forward in this area, as well as in the entire country, would be a campaign for a wide diffusion of the rudiments of sanitation. Even the most primitive conveniences are not available. Slops are thrown out near the house. Plumbing is of the banana patch variety.

Mr. McRae has some 800 acres of pastureland, over 500 of which are improved. He hasn't enough cattle at present to warrant getting the other in shape. He had just sold 40 fat steers, and now has 260 head of horned cattle left. One hundred more will be ready to sell within a year. There are 40 cows that will calve within three months and

SLEEK STEERS FATTENING IN THE LUSH PASTURES
WHERE FORMERLY GREW A DENSE STAND OF RAINFOREST.

30 heifers to calve within the next year. There are 50 cows giving milk now, and 46 calves. Cream is the profitable source of income. White cheese is made of the skimmed milk. He now makes about 400 B. a month from the dairy business, but hopes, with more cows, to make about 1,300 B. a month. Hogs are a kind of by-product of the dairy business—twelve old razor back sows are now being fattened for market and only the better looking ones are being kept. They are fed the whey. The man yells "chun chun chun," and they come running from every direction. They are also fed cooked Guinea bananas which fatten them rapidly. At present they still forage too much. Even so they are not lean

A PASTURE FIELD WHICH HAS BEEN CLEARED OF SMALL TREES
THEN ALLOWED TO REST SIX WEEKS. THE HEIGHT OF THE GRASS MAY BE JUDGED BY THE FACT THAT ONLY THE HEAD OF THE MULE WHICH MR. MCRAE IS RIDING CAN BE SEEN.

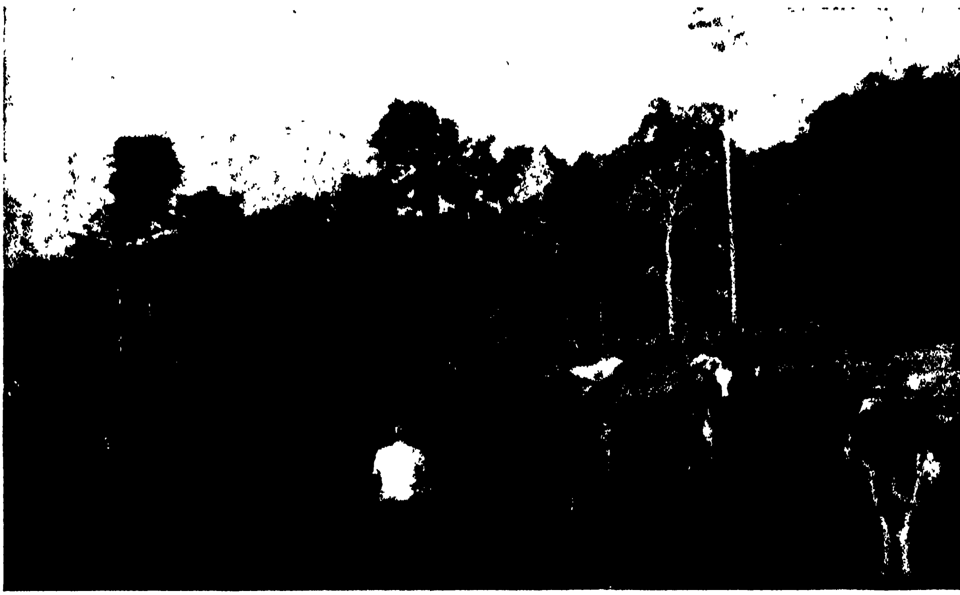
and muscular, but rather fat. When rendered the fat is more like white oil than corn lard, but perhaps it would look different in a refrigerator. The big risk in the hog business is the danger of cholera. Vaccination is necessary every three months if one wants to be sure of not losing them. At present Mr. McRae has about a hundred sows, shoats, and pigs. Only the better looking sows are being kept for breeding purposes, and the herd is being improved by what looked like a Duroc boar.

All the maintenance work in the ranch is taken care of by the Mayordomo, a native Venezuelan, who thus far has proved trustworthy. The cost of upkeep is shared, as is the income from the farm. The only expenses which are borne by the rancher alone are those of expansion. Some steers had just got over the fence into a neighbor's plantain patch. The neighbor wanted 120 B. damage; the judge settled it at one fourth that amount. This was the first time such a case had arisen, and the fine was paid by the owner on condition that from then on such costs would be shared. It is part of the Mayordomo's job to see after fences.

About every three or four months a pasture gets full of weeds and small trees which are cut out at the cost of about a dollar an acre, and the field is left to rest for about six weeks. At the end of that time the fresh pasture of very fattening Guinea grass is higher than the backs of the steers when they are turned in. Quite frequently both grass and weeds are cropped close, corn is planted and acts as a cleaning crop. After it is harvested—in five months—the grass, without reseeding, comes up thick and lush, and makes excellent pasture again. A grass called Paéz is used for milch cows. Ticks don't seem to live well in it. In the ordinary Guinea grass pasture there are many ticks—one gets pretty well covered with them walking through the grass. But there are so many that no attempt is made to kill them; one brushes them off with a leafy branch. If a pasture is left vacant for six months ticks die, apparently of starvation. An important source of income is that derived from pasturing lean steers from the Llanos at 4 B. apiece per month. They are bought in the Llanos for 60 to 80 B., driven across the mountains and fattened in these pastures for six months, after which they are worth at least twice what they originally cost.

A STREAM-LINED, AIR "CONDITIONED" DAIRY BARN IN THE TROPICS

One is amazed, as one travels along the railroad for the first time and suddenly sees the dense tropical rainforest on both



MILKING TIME IN THE TROPICS
THE PRESENCE OF THE CALF, TIED TO HIS MOTHER'S FRONT LEG, AIDS THE COW IN THE PROCESS OF "LETTING DOWN" THE MILK, SO THE MILKER ASSURES US.

sides of the track give way to tall green and luxuriant pasture, as pretty as a field of well-developed winter wheat in May. And in these fields browse cattle hardly visible because of the high grass. They are short haired and as sleek as cornfed Herefords in Illinois or as the milch cows in the rolling pasturelands of England or Brittany.

Thus it is not only possible to cut down tropical rainforest and keep it at bay by planting grass, but it is possible

TWO HORSE LOADS OF PLANTAINS READY FOR SHIPMENT TO MARACAIBO
VIA THE NARROW GAUGE RAILROAD TO ENCONTRADOS, THENCE VIA THE ENCONTRADOS RIVER AND LAKE MARACAIBO TO MARACAIBO.

to do this privately, without government subvention and, at the same time, very profitable. Of all the business ventures I have seen in recent years this seems to have least chances of being a failure. The government might confiscate all large holdings or there might be a shortage of workers, but such eventualities are possible anywhere.

Of course this kind of business can not be hand-to-mouth or self-sufficient. There must be an assured market and transportation facilities to that market. Maracaibo is the market, and the railroad, the Escalante River and Lake Maracaibo, is the means of transportation. The railroad is a good example of what artificial transportation routes mean in the development of a country, even if that country be tropical rainforest. Furthermore, it makes it possible for the ranchers to live in the healthful mountain area, preferably in or around Mérida, and visit their ranches only when necessary. Even before the railroad was built ranches were strong along the various rivers flowing into Lake Maracaibo, as they still are. In this region the soil is exceptional too—rich alluvial and not the usual leached residual, which is indeed difficult to grow crops on. On Mr. McRea's ranch the soil is well drained, yet moisture retaining, so that even in a drought it is not too dry. Yet this same rich alluvial soil must follow all along the eastern side of the great Andean back bone of Central and South America, and the tropical rainforest areas could be cut away and the regions thus complement the densely populated mountain communities of Peru and Ecuador, for example, if only highways and railroads were built, or even good trails over which cattle could be driven to market. The road from Bogotá to VillaVicencio in Colombia, tapping the rich resources of the tropical lowlands, has already proved its value.[3]

The contrast is indeed very great between this intensive cattle ranching where the original natural landscape has been wholly substituted by a man-made one, and the extensive type in the Llanos, where the natural landscape is exploited as found, without any change at all.

In this area the most important factor in making profitable exploitation of the tropical rainforest possible is transpor-

AN EX-MONARCH OF THE FOREST

ORIGINALLY LEFT STANDING FOR SHADE. NOW, WITH MOST OF ITS BRANCHES BLOWN OFF, IT IS A PREY TO CREEPING VINES, AND PARASITIC AND EPIPHYTIC PLANTS

tation facilities which tie the area to a market: the railroad, rivers and Lake Maracaibo. Access to an expanding market has spelled growth and development for many an area which would otherwise have only half heartedly supported a miserable population.

[3] R. E. Crist, "A Cultural Traverse Across the Eastern and Central Cordilleras of Colombia," *Bull. of Pan American Union*, 1942: 132–144.

THE EXPANDING USEFULNESS OF A PORTION OF THE SPECTRUM

By JAMES M. KETCH

ILLUMINATING ENGINEER, GENERAL ELECTRIC COMPANY

In 1672, Sir Isaac Newton announced to the scientific world his conclusions from some experiments which he had been conducting at Cambridge on the decomposition of white light by a prism. In his experiment he admitted the light of the sun into a darkened room through a hole in a shutter. Without the prism, he saw the image of the sun on the opposite wall of the room; when the prism was placed close to the hole, the sun's image spread out in one direction making a new pattern made up of the colors of the rainbow. Later, by means of a convex lens he caused the colors to converge again into the original white light. In this way Newton discovered the solar spectrum.

During the years that followed, Newton's spectrum—now known as the visible spectrum—grew enormously at both ends. By research, it has been extended beyond Newton's spectrum through the shorter wave lengths of ultra-violet, x-rays and gamma rays, to the shortest cosmic rays, and beyond the longer visible wave lengths to include infra-red, radio, and the longest electric waves of electric generators.

If we were to discuss intelligently the complete known spectrum it would be necessary to include the work of the medical profession, the x-ray specialist, the radio engineer, and the electrical transmission engineer, as well as that of the illuminating engineer. Our discussion will include only applications of energy sources from the visible region and those on either side: the ultra-violet and the infra-red.

We are under the stress of war with its urgent call for more and more industrial production and it is fitting, therefore, that we stress the expanding usefulness of our spectrum because of the increasing benefits to industry in the applications of the new light and radiant energy sources during the present emergency.

The Visible Spectrum

The white light, of the visible spectrum, has served mankind throughout the ages. Typical sources, which in addition to visible light also produce infrared and ultra-violet, include the sun, natural daylight, arc lamps, and incandescent filament sources. The break up of the light from those sources into the component colors of its spectrum has, until the past few years, been of academic and secondary interest to the majority of illuminating engineers. To them, the spectrum was an interesting bit of science studied in the college physics laboratory and written up in experiments which started with "Purpose of the Experiment" and ending with "Conclusions."

They were interested, naturally, in the individual colors for decorative purposes, but applications were limited because of the inefficient methods of obtaining such colors. To obtain some colors —blue or green, for example—from incandescent lamps it was necessary to absorb, and waste, 80–95 per cent. of the generated white light, and even to obtain a near-daylight quality, one third of the light was absorbed by a blue filter glass bulb.

Of more importance to the lighting engineer than color, a decade ago, was the control of white light by means of reflecting, refracting and diffusing media

into candlepower distribution patterns that were most useful.

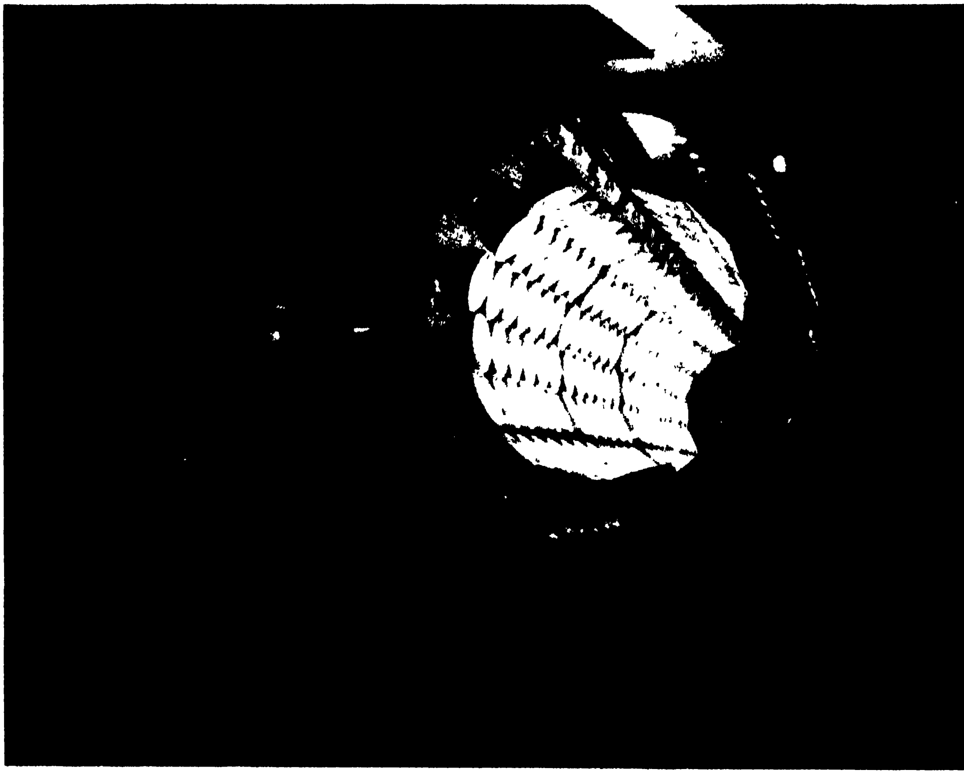
Beginning with World War I and increasing rapidly during the years that followed, the broader interest of the lighting profession was in footcandles and glare. These two came to be called popularly "positive" and "negative" light because the higher the footcandle value—positive light—on objects to be seen the greater was their visibility, but with more and more glare—negative light—less and less could be seen.

Researches under way following the war were based on a new concept that the human being is a complex seeing machine. As these researches on seeing became better understood there evolved a basis for the application of footcandles and reduction of glare called the Science of Seeing. This new science indicates that, for optimum seeing, the human being requires hundreds of footcandles rather than the ten, or less, then in common use for industrial purposes. It has been but recently, however, that the light sources, equipments, and application methods have been developed for obtaining those higher lighting levels comfortably.

Fortunately, the present emergency finds us with efficient and versatile new light sources, controlling equipments, and methods of applying them, that make the higher levels of 50, 100 and even 500 footcandles both practicable and economical. There has been a convergence also of several wide-spread researches under the sponsorship of the Industrial Lighting Committee of the Illuminating Engineering Society. These researches have contributed much

TYPICAL MODERN INDUSTRIAL DRAFTING ROOM

WITH CONTINUOUS ROWS OF FLUORESCENT TROFFERS THREE FEET APART. THE MAINTAINED ILLUMINATION IS ON THE ORDER OF SEVENTY-FIVE FOOTCANDLES.



TYPICAL BANK OF INFRA-RED DRYING LAMPS
MOUNTED ON A CONVEYOR LINE WHICH CARRIES PAINTED PARTS THROUGH THIS TUNNEL. DRYING IS ACCOMPLISHED DURING THE SHORT TRAVEL. INFRA-RED HEATING DEVICES TAKE MANY OTHER FORMS TO SUIT THE INDUSTRIAL PROCESS.

on methods of applying light to many of the difficult and diverse visual tasks of industry.

Daylight quality and colors in some of the newer light sources are produced directly, and at high efficiencies, rather than by the absorption methods of five years ago. Because of the lower brightness of the fluorescent lamps, less shielding of the sources from direct view is necessary than that required for the higher brightness incandescent sources. The fluorescent lamp is tubular in shape and requires entirely new types of reflecting equipments and methods of application. The efficiencies of some of the mercury and fluorescent light sources compared with those of standard incandescent lamps are shown in the following table.

Lamp	Lumens per watt	Rated av. life hrs.
Incandescent, 1000 watt	21	1000
Mercury vapor, H-1, 400 watt	40	3000
Mercury vapor, H-5, 250 watt	40	2000
Mercury vapor, H-9, 3000 watt	40	2000
Fluorescent (3500°) 40 watt	52	2500
Fluorescent (3500°) 100 watt	42	3000
Fluorescent (daylight) 40 watt	42	2500
Fluorescent (daylight) 100 watt	37	3000
Rectified fluorescent, 85 watt	47	3000

The spectra of two of these lamps—the 400 and 250 watt mercury vapor—are discontinuous, or banded, and therefore have the general color characteristics of the older Cooper-Hewitt lamps: not suited where color discrimination is important, but applicable for general industrial lighting purposes.

As we review some of the applications of these lamps to a wartime industry two factors stand out as important: (1) The high footcandle levels (30 to 500) required for optimum seeing are practicable and generally accepted; (2) there is a definite trend toward lines of light of relatively low brightness which can be conveniently applied to lines of machines, benches, and conveyor lines.

Lines of light, areas of light and higher illumination values have found their way likewise into drafting rooms, offices, and stores. In offices they are conveniently combined with acoustical ceiling materials.

As was stated earlier, in order to obtain colors from the incandescent lamp it is necessary to absorb all unwanted rays of the visible spectrum, and consequently the production of most colors from incandescent lamps is extremely inefficient. The production of colored light by fluorescent lamps, is, however, very efficient—green being nearly two hundred times as efficiently produced as by incandescent sources. The production of daylight spectral quality reduces to the simple problem of mixing the phosphors of several colors in proper balance as contrasted with the subtractive filter method employed in daylight incan-

CONTINUOUS ROWS OF FLUORESCENT LAMPS

USUALLY EMPLOYING TWO 40- OR TWO 100-WATT LAMPS IN EACH ROW. THIS TYPE OF LAMP HAS BECOME FAIRLY STANDARD IN THE MODERN FACTORY.

descent lamps. These possibilities of producing color at high efficiencies give the lighting engineer new dimensions of color and colored light applications.

A recent investigation by a lighting engineer and an industrialist on "Improved Vision in Machine Tool Operations by Color Contrast" shows some very interesting possibilities for increased war time production, and indicate a renewed interest by lighting engineers and users in the logical coordination of light and paint to achieve pleasant surroundings and increased ease and comfort in seeing.

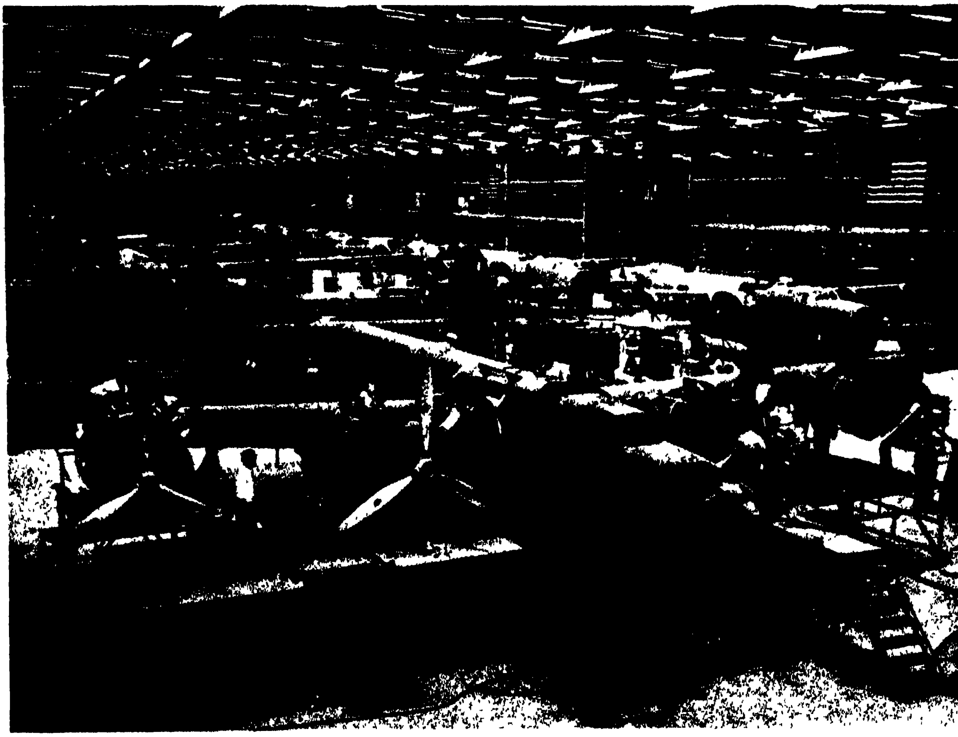
Another light source not listed above is the 1000 watt, H-6 mercury lamp which is about the size of a cigarette. It has a rated life of seventy-five hours and has an efficiency of sixty-five lumens per watt. Its application is now devoted chiefly to the photochemical processes—engraving, television, also searchlights. It is a source rich in ultra-violet radiation and is finding applications for other chemical and photo-chemical conversion processes that require large quantities of ultra-violet radiation. This lamp requires cooling either with forced air or by means of a water jacket around it and some means of circulating about 3 quarts of water per minute to keep operating temperatures of the quartz tube within safe limits.

All fluorescent and mercury arc sources require ballasts to control their arcs. The wattage consumed in such ballasts must, of course, be added to the lamp wattages when figuring ultimate over-all efficiencies.

Infra-red Region

Beyond the red end of the visible spectrum is the longer wavelength infra-red

USE OF FLUORESCENT LAMPS IN AN OFFICE ROOM



VIEW OF LIGHTING IN A LARGE AIRPLANE ASSEMBLY PLANT
EACH INDIVIDUAL REFLECTOR CONTAINS TWO 85-WATT TYPE RF FLUORESCENT LAMPS.

region which manifests itself as radiant heat. Since incandescent lamps normally radiate eight to twelve per cent. of input energy as visible light and from sixty to eighty per cent. as infra-red radiation, it is natural that they should find applications for radiant heating purposes.

For some applications requiring invisible infra-red only, lacquer and glass filters are available which are opaque to visible radiation but which transmit most of the infra-red. New photoflash lamps operating on this principle have but recently been made available. These lamps which produce very little visible radiation, used in conjunction with standard infra-red films, can serve news photographers under forced blackout conditions if necessary.

Each war brings with it accounts of secret and invisible rays capable of doing incredible damage to enemy fleets and airplanes. We quote from R. A. Houston's interesting text "Light and Color."

The possibilities of invisible rays have always appealed to the imagination of inventors and cranks, and, as any one connected with the government departments dealing with inventions knows, there were many mad schemes proposed for using them during the war. The infra-red rays or heat rays have been on the whole the more popular. They have a quite respectable antiquity. Archimedes, the most celebrated mathematician of ancient times, is said to have set the Roman fleet on fire, and destroyed it at the siege of Syracuse in 212 B.C. by concentrating the heat rays of the sun upon it with concave mirrors. The fleet was then one bow shot distant from the walls. (But the story is either a pure invention or arose from a misunderstanding.)

Napier of Merchiston (1550–1617), who discovered logarithms, also proposed to destroy an enemy's ships by heat rays, as part of a general scheme "for defense of this Iland" and the rendering of Britain safe from all her enemies.

And H. G. Wells in the "War of the Worlds" has let his imagination play upon heat rays in

INSTALLATION OF FLUORESCENT LIGHTING BY CEILING TROFFERS
SUPPLEMENTED BY SEVERAL GERMICIDAL UNITS MOUNTED ABOVE THE BLACKBOARD TO IRRADIATE THE AIR AS IT CIRCULATES IN THE UPPER PART OF THE ROOM.

an unfettered manner, and easily outdistances both Napier and Archimedes. The heat ray was the Martian's chief weapon of war. It was a noiseless and blinding flash of light which carried miles. Pine trees burst into flames, as the shaft of heat passed over them, and every dry furze bush became with one dull thud a mass of flames. It blotted out all living things, and in its track the dark ground smoked and crackled.

Important to our wartime industry has been the development of a line of heat-generating incandescent lamps called drying lamps. These lamps operate at a low luminous efficiency which makes them of little value as light sources but their use is being rapidly expanded for many industrial processes requiring heat for the curing or polymerization of paints or lacquers, for the evaporation of moisture, and for mass heating of materials.

The speeding up of production implies a reduction of the time for manufacture and processing of materials and a conservation of productive space. For many industrial heating problems both time and space can be conserved by drying-lamp applications. The advantages of this type of heating are apparent because by this method (1) greater concentrations of energy possible on the work speed up the drying time (savings as high as 90 per cent. of the time are possible), (2) smaller and less expensive ovens are practicable, (3) ovens can often be placed above the floor thus releasing productive space for machine tools, (4) graded temperatures can be obtained on a constant speed conveyor by the spacing or wattage of the lamps used, (5) there is no heat-up or cool-off time necessary, and (6) the interiors of

factory spaces can be made more comfortable for the workmen since it is not necessary to heat the factory interior as is usually the case when heated air methods are used.

Ultra-violet Region

Yesterday, a scientific fact; today, a production tool. The mercury arc, used as a basis for many of the new light and radiant energy sources, has a number of characteristic lines and bands both in the ultra-violet and visible sections of the spectrum. By a control of the pressure within the tube housing the arc the amount of energy in those lines or mercury bands is under some control. For example, the pressure in fluorescent lamps is very low which makes it possible to convert a half of the electrical energy into ultra-violet energy at one of the principal mercury lines, 2537A. By using the proper phosphors—fluorescent and phosphorescent materials—much of the energy of this invisible 2537A radiation is converted by fluorescence to the visible region. Not only are colors obtained directly by using the proper phosphors but, by mixing the right phosphors, white light is obtained at much higher efficiencies than those of incandescent lamps. This method of producing light makes low-temperature, low-brightness sources practicable.

For the purposes of this discussion we are interested in three principal parts of the ultra-violet region. One centers around 2650A and has a germicidal, germ-killing, action. The second centers at 2967A, which is the peak point of the erythemal effectiveness. The third centers around 3650A at which point we find photographic and fluorescent effects.

AN APPLICATION OF BLACK LIGHT—NEAR ULTRA-VIOLET
TO IRRADIATE THE CEILING DESIGN PAINTED IN LUMINESCENT PAINT.

The first practical venture into the ultra-violet region was made several years ago with the development of the S–1 and S–2 sunlamps. These lamps duplicate sunlight in a practical way. The source of radiation is a combination incandescent filament and short mercury arc. By means of a special glass bulb the short waves, which are shorter than those reaching us from the sun, are absorbed. These lamps found use by the medical profession as sources producing Vitamin D, substituting for codliver oil, and in the treatment of rickets. Their use in homes in the winter months gives the beneficial effects equivalent to a summer sunshine.

More recently another section of the ultra-violet region has claimed our attention. The bactericidal effect of ultraviolet radiation has long been known. The recent development of efficient sources of this germicidal radiation makes possible its practical use in many hygienic and industrial problems involving organisms ranging from mold spore to pathogenic germs and viruses.

The lethal action of ultra-violet is characteristic only of those wavelengths which penetrate, and are absorbed by, the bacterial organisms. For practical purposes this spectral range is from 3000A to 2000A, with a maximum at about 2650A.

It is a remarkable coincidence that one of the principal mercury lines, the 2537A resonance radiation line of the mercury arc, is very close to the 2650A line of maximum bactericidal effectiveness. This is the same line used in the fluorescent lamps to produce a visible fluorescent effect from the phosphors inside the glass tubes. By enveloping the mercury arc in a special glass tube which has some of the characteristics of fused quartz, it is possible to transmit appreciable amounts of bacteria-killing radiation.

By far the most important application of these sources of ultra-violet light has been in the germicidal treatment of air to kill air-borne bacteria. Many of our diseases are transmitted by air-borne bacteria which are relatively inaccessible and can not be killed by ordinary germicidal agents without creating objectionable effects in the air itself. Heat may serve as a germicidal, but there remains the problem of its removal. Air washing and filters are effective, but are more limited to forced air systems.

A simple solution is to employ germicidal lamps in interiors with the lamps shielded from view. The natural convection and circulation of the air carries the bacteria past the sources where they are killed. One 30 watt germicidal lamp irradiating the upper half of a 4000 cubic foot room produces the equivalent sanitary ventilation of 100 changes of air per hour. Such actual changes of air per hour by means of outdoor openings and windows would be impracticable during most seasons, and perhaps bothersome at all times.

These new germicidal lamps have applications in hospital operating rooms and where barriers are created at doorways between cubicles. They have many possibilities of use in schools, stores, theatres, recreation rooms and military barracks where numbers of people congregate.

Other applications have been made in the air ducts of ventilating systems, and for direct application in the sanitary storage of drinking classes, dentists' instruments, etc. They have been applied to the sterilization of milk bottle caps, sanitary packaging and processing, and in the sterilization of hotel bathrooms.

The third section of the ultra-violet region of interest to us is that nearest the visible spectrum. It is the one popularly known as "black light." It happens that one of the principal mercury

arc spectrum lines is at 3654A. The excitation range of many materials that fluoresce is a fairly broad one that peaks at about this same wavelength. Since all of the mercury arc sources also produce visible light, it is necessary for some applications to use filters over them which efficiently transmit the ultra-violet and absorb most of the visible. There are also phosphors which, when used in the fluorescent lamps, produce this same general effect by converting the energy of the 2537A-line to a longer ultra-violet, plus some visible light.

Of course the dramatic and decorative effects of black light sources used in connection with fluorescing and phosphorescing materials are well known. Of most importance to us now they find their use industrially for the inspection of many organic and inorganic substances. It is very possible also that those materials which phosphoresce will find usefulness during blackout conditions to mark machines, gun turret instructions, tunnel and shelter entrances, pathways, roads, exits, etc.

May we conclude, then, with the thought that Newton's visible spectrum has increased in its importance not only in the new attitude regarding seeing, production, safety and defense, but our interest has expanded and found added usefulness in the invisible infra-red, and in three sections of the ultra-violet. We can, today, pick the points on the ultra-violet, visible, and infra-red regions that we want to use, and find practical, workable, light or radiant energy sources to produce those wavelengths.

VALUES NOT EASILY REGAINED

In this Review, three years ago, under the heading "Night over Europe," an attempt was made to describe the disaster which the war was bringing to universities and laboratories both in England and on the Continent. The processes of disintegration had already begun. Institutions dedicated to the extension of knowledge were being geared into the war machine. The necessities of military mobilization had decimated faculties and student bodies alike. Cultural values upon which civilization is based were being thrown to the winds as the intellectual blackout spread across half the world.

Today the long shadows of the blackout are lengthening inexorably over the United States. We are fighting for a future in which free institutions can live, but to achieve that end we are sacrificing values which, once they are lost, are not easily regained. The crisis presents us with a problem of delicate balance: how to win the war and at the same time preserve those intellectual ideals and standards, those "great things of the human spirit," without which a military victory would in the end be nothing but ashes. History shows us that it is possible to lose a civilization even while armies and navies are triumphant.

As in Europe, so here at home, liberal education has been discarded for the duration. Our universities are now instrumentalities of total war. Technology is left as the one subject which must be taught. History, economics, literature, philosophy—the whole range of the social sciences and the humanistic studies—have been crowded out of the picture by the pressure of higher priorities. Our young men are not to be trained in liberal understanding; they must be made into soldiers. Of necessity, their education must be an education in violence. Their participation in the cultural and social heritage of civilization is adjourned. For the time being, at least, their generation may not share in the humane tradition on which alone the building of a worth-while future depends.—*Raymond B. Fosdick in the Rockefeller Foundation Report for 1942.*

FLUCTUATIONS IN THE ABUNDANCE OF THE ALASKA HERRING

By EDWIN H. DAHLGREN and L. N. KOLLOEN

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SINCE man first began harvesting the wealth of the sea, he has found the herring to be among the most valuable resources placed at his disposal. Because their range includes nearly all the temperate waters of the northern hemisphere, they have been readily available to large masses of people. They are found in dense shoals, consequently are easily captured, which makes them a cheap source of tasty and nourishing food. Then, too, they have been found to be ideal for processing into meal and oil, the former to be used as a food for livestock, the latter for the host of purposes to which animal fat has been found adaptable. This processing has greatly enhanced their value in commerce of recent years. In addition to these direct uses, the herring are of tremendous hidden importance in that they provide food for a multitude of larger forms of fish and mammals which, in turn, are of economic value. Truly the herring hold a key position in the chain of nature by which the boundless quantities of microscopic life in the oceans are changed to a form usable by man.

Although the Pacific herring (*Clupea palassii*) is of less importance in the world economy than is the closely related Atlantic form (*C. harengus*), it supports an industry in Alaska alone which employs hundreds of men and contributes millions of dollars in new wealth to the nation each year. In this, as in other of our valuable natural resources, a conflict exists between the interests of exploitation on the one hand and those of conservation on the other. It is the contention of the former group that the supply of herring is virtually inexhaustible, and that the fluctuations in yield which are so evident in the fishery are due solely to the chance occurrence of conditions which determine whether or not the herring stocks will be available to the fishermen. This contention should be critically examined.

That great fluctuations occur in the herring fishery becomes evident from an examination of Fig. 1, which shows the production of the three areas which have been most extensively exploited during the past quarter century. Since no measure of the amount of fishing effort expended in making these catches is included, this chart can not be construed as indicating true abundance of the stocks. The Southeastern district, which was the first of these areas to be developed, has been devoted primarily to a reduction industry in which the fish are processed to recover the oil and meal. Until the decline in abundance, which occurred there in recent years, it was by far the greatest producing area in the Territory. The Prince William Sound and Kodiak districts were more recently developed, first as a source of the mild-cured product, more recently as reduction fisheries.

In each of these districts the fluctuations in catch which followed their initial period of expansion have been due in some measure to changing economic conditions which have governed the demand for the products and so governed the amount of fishing effort expended. Aside from this, however, the supply of

herring has been so erratic as to have resulted in much economic loss. The question arises as to the causes of these great fluctuations in the supply available. Were they only a reflection of changes in availability of the schools to the fishermen, or were they due to real fluctuations in the abundance of the stocks on which the fishery has depended?

Such fluctuations in the abundance of herring, with corresponding fluctuations in the catches made by the fishermen, may be attributed to one or more of the following factors:

Changes in the availability to the fishermen from year to year of the schools of herring at the usual fishing grounds. These changes may be quite independent of the true abundance yet result in great variations in the catch made by the fishing fleet.

A significant reduction in the abundance level of the species as a direct result of the removal from the stocks of the tremendous numbers of fish required to support an intensive fishery.

Natural fluctuations in abundance, the result of varying degrees of success attending spawning so that in some years a large number of recruits enter the adult stocks, in other years but few. This might occur largely independently of the changes in availability or of the withdrawals imposed by the fishery.

Changes in the migration routes of the herring with the abandonment of the usual feeding grounds in favor of other grounds unknown to the fishermen. Such changes would result in fluctuations quite independent of those caused by any of the above considerations.

It must be realized, before a true understanding of this problem is possible, that each of these fishing districts is supported by a body of fish resident therein and independent of each of the other areas. A rise or decline in abundance in any of these districts will not necessarily be reflected in similar fluctuations in the others, since each is dependent on separate bodies of fish. Furthermore, within each of these major districts there are known to be individual bodies of fish which do not mingle with adjacent groups, but which remain as

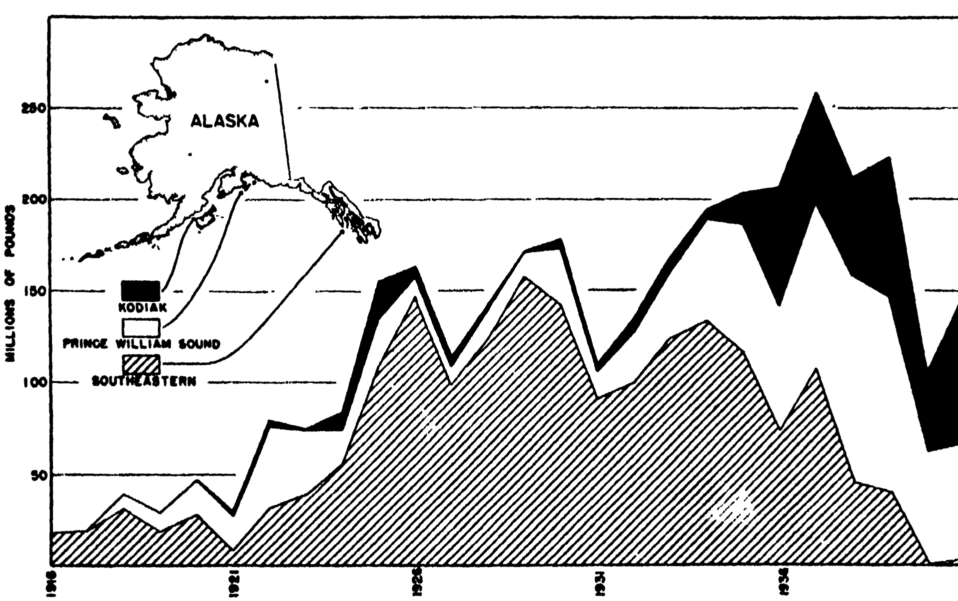

FIG. 1. PRODUCTION OF HERRING

IN THE THREE MAJOR PRODUCING AREAS OF ALASKA DURING THE PAST QUARTER CENTURY. THE INSERT SHOWS THE LOCALITIES OF THESE PRINCIPAL FISHERIES.

distinct stocks with feeding and spawning grounds separate from the others and with different migration patterns. The verity of these assertions has been established by the statistical analysis of biometrical data (racial analysis) and by extensive tagging programs. The independence of the herring populations between areas, and even within areas, is of particular significance in that it alters entirely the problem of conservation. If the herring along the coast were of one stock, then extensive withdrawals in any of the localities now being exploited would be replaced from that common stock. Since, however, each of these localities is supported by a separate body of fish, over-exploitation in any one area will lead to a decline of that population without chance of replenishment from stocks in other areas. This may lead to a failure of the fishery in that locality without affecting the status of adjoining populations. Any discussion of abundance must hold this as a fundamental premise.

To return to the discussion of the causes for changes in abundance, the first of the factors mentioned above which govern the catches of the fishermen—that of changing availability—may be expected to play an important part in determining the quantity of fish taken from year to year. It must be recognized that the catch for any one year might easily be influenced in part by weather conditions governing the activities of the fleet, or by other causes affecting the behavior pattern of the herring. Therefore, a rise or decline of the catch in a single year over that of the preceding season is not sufficient evidence on which to base any conclusion on abundance. This factor of availability, however, as reflected in the average catch from season to season, tends to be compensatory, since for each season in which adverse conditions have resulted in poor catches, there has been a season in which favorable conditions have led to good yields. Obviously no continuing decline in the catch would result from this factor alone. A trend showing reduced catches continuing over several years, such as has occurred in the important fishing grounds of southeastern Alaska, and which has become evident in the Prince William Sound and even in the Kodiak catches of recent years, can not be ascribed to variations in availability alone.

On the other hand, as the technique of fishing has improved through the years the fish have, in effect, become more available to the fishermen in proportion as improvements have contributed to making the gear more effective. Increased knowledge gained through fishing the same grounds year after year, together with improved methods and equipment have served to increase the effectiveness of the fishing gear. Outstanding improvements have been an increase in size, seaworthiness and speed of vessels, the use of power in handling fishing gear, and the introduction of radiophone equipment. Many another innovation in fishing technique has resulted in increasing the effectiveness of the vessel as a fishing unit. Unlike the hydrographic factors mentioned which govern the availability of the species to the fishermen, which are compensatory, these improvements have been cumulative in their effect. If the abundance of herring had remained constant through the years, one would expect continuing increased catches as a result of these improvements. This has not been the case. Thus it becomes even more apparent that this changing availability can not be held responsible for any long-term fluctuation in abundance, and the declines of recent years can not be attributed to this factor. The fundamental cause of these fluctuations must be sought elsewhere.

The second factor to be considered—that the withdrawals made by man may result in a reduced abundance level—can

not be lightly disregarded. The balance of nature is such that, even without this added withdrawal, the species succeeds only in maintaining itself and does not increase beyond bounds. Natural predators, of which there are many, take a huge toll from the stocks each year. When the demands of man with his highly efficient gear for the capture of herring are added to those of the natural enemies, the result must inevitably be a reduction in the total numbers of individuals of which the stocks are comprised.

The question arises as to whether or not these inroads of man have been a significant factor in bringing about the declines which have been observed. There is considerable evidence to indicate that they have been, and little or none to disprove it. As each new district has been invaded by man, the abundance levels have been found to be high, and in each case have shown positive declines following periods of intensive fishing. The declines, too, have followed a definite pattern. Those areas first and most intensively exploited have been the first to decline; those more recently opened have followed in the same proportion as the intensity of the fishery. It is unmistakably apparent that the withdrawals of the most efficient of all the predators—man—has had a significant effect on the abundance of the species. Until proof to the contrary becomes evident, man must assume his share of the responsibility for the decimated stocks in areas of continued intensive fishing.

The third factor mentioned—that of the natural fluctuations which might be expected to occur quite independently of the fluctuations made by man—have been shown to exist to a marked degree in the herring as well as in many other species of fishes. These fluctuations result from the varying degrees of success which attend the spawning from year to year, so that the young surviving to the age at which they enter the commercial catch may be exceedingly numerous in some years and in other years exceedingly scarce. When the former situation occurs, there follows a marked rise in the abundance level of the stocks involved. This increased abundance level continues until this group has been reduced either from natural or from imposed mortality. Conversely, the failure of any spawning to contribute a normal share to the replacement of stocks reduced by the mortality during the preceding year, leads to a decline in abundance—a decline which may continue until a new successful spawning again replenishes the stocks by the contribution of an abundance of new recruits.

Continuing records of the age of fish present in each year's catch show that this condition applies very clearly to the Alaska herring. Since the age of the individuals can be determined in this species by examination of the scales, it is possible to establish the percentage of the total represented by each age in the adult stocks, and so appraise the contribution made by the offspring of each spawning to the total population. In occasional years the recruits entering the catch appear in great abundance—indicating that an unusually large number of the offspring of that spawning had survived—and this age group continues to constitute a large percentage of the total for several succeeding seasons. The contribution of such a dominant group may be as high as 90 per cent of a season's total catch. It has been demonstrated that in the past fifteen years there have been two such exceptionally successful spawnings (1926 and 1931) and three which were fair producers (1929, 1935 and 1936). The remaining spawnings, especially those of 1928, 1932, 1933, 1934, 1937 and 1938 were mediocre or poor, contributing but little to the stocks. Fig. 2 portrays the age composition of the important Cape Ommaney stock of

the southeastern district for eleven years following 1929.

The distribution of ages shown is typical not only of this stock in southeastern waters but also in those of Prince William Sound and Kodiak. Whatever the factors responsible for the survival of the spawn, they are of such widespread character that they affect the stocks in all districts much alike. It was the offspring of two phenomenally successful spawnings (1926 and 1931) which have largely supported the Alaska herring fisheries since 1929. The fortuitous entrance in 1934 of the offspring of the 1931 spawning, occurring simultaneously with the disappearance of the 1926 year class, bolstered the abundance levels which would otherwise have fallen sharply. With the subsequent decline in abundance of the 1931 year class from natural and man-made mortality to a point at which it was no longer able to contribute a large share to the catch, there followed the decline in abundance of the southeastern fishery which became so evident after 1937. The increments provided by the 1935 and 1936 year classes were not sufficient to check this decline for long, although their contributions served to postpone it. This same condition has been reflected in the catches in Prince William Sound since 1938, and has been felt more recently in the Kodiak area.

While the 1935 and the 1936 spawnings have aided in sustaining the yields of these fisheries with their contributions to the stocks, they alone have not been of adequate numerical strength to fully reimburse the stocks for the withdrawals which have been made, and a continuing decline in yield may be expected until a new abundant age class enters the catch. When this will occur no one can predict, and until such occurrence man must temper his demands on what remains of the stocks in order to insure the survival of a sufficient number of individuals to

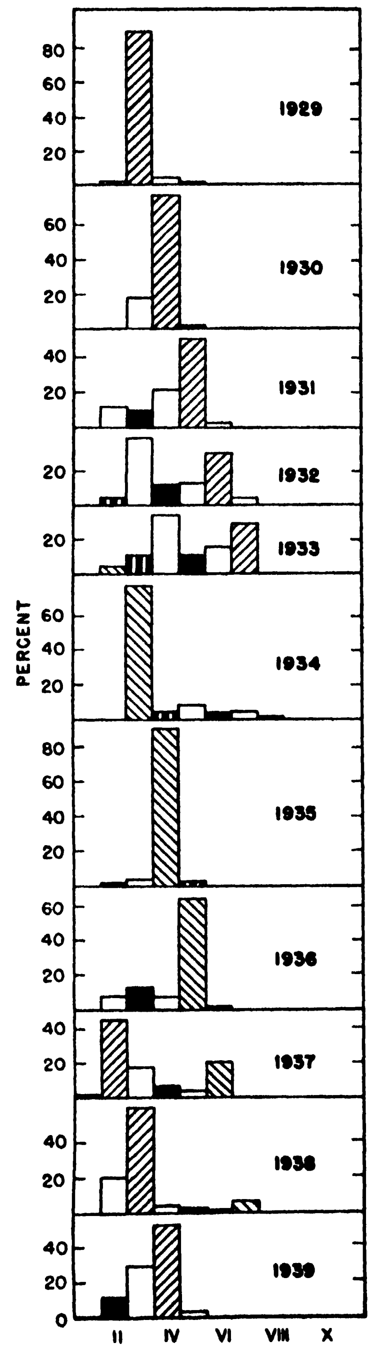

FIG. 2. DOMINANT AGE GROUPS
ARE SHOWN IN THIS GRAPH OF THE PERCENTAGE AGE COMPOSITION OF THE HERRING TAKEN AT CAPE OMMANEY IN SOUTHEASTERN ALASKA.

produce a future successful spawning when biotic conditions are favorable to such an event. With the influx of such a group renewed activity can be anticipated in all the fishing areas.

The fourth factor—basic changes in migration patterns of the stocks of herring—if existent would render invalid any evidence of decline based on the reduced catches made by the fishermen on the customary grounds. The reasoning most often used to explain poor catches by those reluctant to accept the possibility that declines in the actual numbers of individuals comprising the stocks have occurred, is that the herring failed to "set in" for one or more years. There is no evidence to support this theory, and much to refute it. As each new area was exploited, the abundance was found to be high; continuing intensive operations have always led to declines. In those instances within our knowledge where reduced population levels have been reestablished at high levels, these increases have followed the entrance into the ranks of the adults of recruits from an exceptionally successful spawning. Each time declines have again followed as these individuals in turn have succumbed to their many enemies. Of recent years it has been demonstrated that nine out of fifteen spawnings have failed to provide adequate replacements to the adult stocks. Declining abundance levels must inevitably follow such an unfavorable replacement record. Thus, with each major fluctuation explainable in terms of abundance, there seems little reason to believe that abrupt changes in migration of the stocks can be held responsible for the declines and failures in the fishery.

It has become ever more apparent as the knowledge of this species has increased that the Alaska herring are not as productive as are other closely related forms. A close relative, the Atlantic herring, has an effective fecundity far above that of this species. The catches of Atlantic herring have been tremendous, yet in most cases there has been no indication of depletion. In this regard Aage J. C. Jensen states in a discussion on the laws of decrease in fish stocks,[1] "Fisheries are everywhere of so high an intensity that few food-fish reach an age at which the natural cause of death would be old age. One exception, however, might exist in a part of the Norwegian spring-herring stock, which is so slowly reduced that even 20-year-old specimens are not at all rare in catches." This is a situation quite different from that of our Alaska fishery, where few individuals attain an age of over eight years, at least in those stocks which are heavily exploited.

The demands of the fishery must, of necessity, be reduced to fit the productive capacity of the species. The size of the harvest which may be reaped without endangering the future spawnings by reducing the stocks too drastically, will be dependent on the effective replacement rate. If the low rate of the past fifteen years be the normal one, then it is quite apparent that continued large withdrawals can not be made. If, on the other hand, nature provides more bountifully in the future by furnishing a series of more successful spawnings, then, and then only, can man increase his take without endangering the supply. Time alone holds the answer.

[1] Conseil Permanent International pour l'Exploration de la Mer; Rapports et Proces-Verbaux Des Reunions. Vol. CX, 1939.

THE SKEPTIC AND THE ENGINEER: A STUDY OF HUME AND WATT

By RUFUS SUTER
LIBRARY OF CONGRESS

When James Watt, a young civil engineer in Glasgow, obtained his first patent on an improved steam-engine in 1769, the librarian David Hume had retired to Edinburgh. Possibly these two Scotchmen never met for Watt had not yet proved his worth, and the popular home which was opened three years later at the corner of St. David Street was reserved for brilliant exponents of the pure intellect. Nobody would have guessed that an impoverished engineer without formal education was about to start an economic revolution to transform the world. If the two had met, if the critic of the scientific outlook and the wielder of the scientific technique had matched their wits, something of importance to the understanding of the nature of science might have resulted.

There was more in common between Hume and Watt than appears on the surface. We may marvel at Hume's versatility. Librarian, historian, philosopher, economist, essayist, diplomat, he was equally at home gathering historical data at the library of the Faculty of Advocates in Edinburgh, or talking with Madame de Pompadour in the court of Louis XV. But Watt also was versatile and not uncultured. It seldom is appreciated that he was trained as a mathematical instrument maker and that his skill in this trade, combined with an interest in astronomy, led to his appointment, while still young, as technician to the Macfarlane Observatory at the University of Glasgow. He was also, one should remember, a co-discoverer of the chemical composition of water along with Priestley and Cavendish.

The significant common ground between Hume and Watt, however, was their inheritance of the British empirical tradition. If we recall the history of English thought we will place Hume at the end of a line beginning with Francis Bacon who gave an empirical interpretation to the methodology of the sciences. Among the men in this line were pioneering scientists like the chemist Boyle and the physicist Newton, and philosophers like Locke and Berkeley who speculated about the sources and limits of knowledge. One and all, they emphasized the value of the senses as avenues to information about nature and themselves. We have spoken of this as the British empirical tradition, which is not quite accurate. The thinker who certainly was the first to ply the new method with unquestionable success was an Italian, the father of modern dynamics, Galileo, whose disciples in Italy (such physicists as Torricelli) gave him lusty support. It is, nevertheless, accurate in general to call empiricism a British movement since on the Continent, west of Italy, in the great universities of the Low Countries and in the élite circles of Paris, scientific thought was dominated by the disciples of Descartes, who sought to base knowledge on a kind of rational intuition rather than on sensory observation. And Galileo, himself, as we shall see later, was an empiricist only in a "loose" sense.

To think of Watt as consciously belonging to either of these traditions may seem paradoxical. A man whose excellence was in doing rather than in reflective thinking will strike one as in

another dimension of activity from that in which such philosophical distinctions have meaning. We have nothing from Watt's quill to indicate that he had the least interest in the struggle between the Cartesians and Newtonians. But it is possible to reconstruct the guiding thought in the back of his mind from his reading.

Here again, however, we can not assign to one tradition or the other. The authors he read: for instance, the Frenchmen Bion[1] and Belidor[2] and the German Leupold,[3] were themselves engineers and mechanics and as unconscious of the basic problems of the theory of knowledge as he. But perhaps one may assume that if these men were influenced by Descartes at all it was only in their use of analytic geometry, which he invented, and in a sympathy with the mechanistic world-view which one branch of his spiritual descendants championed. Newton would have interested them in his work on the theory of gravity, and in his optics.

One book read by Watt was definitely Newtonian. He studied it before he left his father's home, and as a supplement or perhaps impetus to his mechanical and astronomical bent it no doubt left a deep mark upon his youthful mind. This work, an introduction to Newton's experimental philosophy, was by a Dutch professor, 's Gravesande,[4], at the University of Leyden, who had known Newton personally. The English translation, which Watt read, was by another celebrated Newtonian, the French refugee Desaguliers,[5] who was the first popular lecturer on scientific subjects in London.

'S Gravesande's book treated of most topics of interest to the physicist: body, motion, gravity, pressure and resistance of fluids, air as an elastic fluid, refraction and reflection of light, the system of the world, etc. It emphasized the reign of law. What is of particular interest to us, however, is the long preface in which the methodology of Newton is stated in admirably clear and precise language. The function of the scientist, according to this preface, is not to speculate about first causes, the foundation of law, or the substance in which observable properties (the phenomena or "appearances") inhere. His task is to observe the phenomena and by a process of induction to arrive at natural laws. The scientist's concern, in other words, should be with the observable and not with invisible intangible metaphysical abstractions, nor even with *a priori* knowledge of the visible. Even the principles of mathematics have their basis in experience. Nevertheless, the preface commends the classical principles of uni-

[1] Nicolas Bion, 1652–1733. *Traité de la construction et des principaux usages des instruments de mathématiques*, Paris, 1752. Watt read the 1-st ed. of the English translation by Edmund Stone (d. 1768) published in 1753. Stone, who greatly enlarged the original, was a student of Newton's *Principia*, and a member of the Royal Society.

[2] Bernard Forest de Belidor, 1693–1761. *Architecture hydraulique*, 1-re ptie., 2 t., Paris, 1737–39; 2-e ptie., 2 t., Paris, 1750–53.

[3] Jacob Leupold, 1674–1727. *Theatrum machinarum hydraulicarum*, 2 bde. in folio, Leipzig, 1725. Watt learned German to read this.

[4] Willem Jacob Storm van 's Gravesande, 1688–1742. *Physices elementa mathematica experimentis confirmata, sive Introductio ad philosophiam Newtonianam*, Lugduni Batavorum, 1720. This work went through several editions, and was translated into Dutch, English and French. In an age when scholars were either Cartesians or followers of Locke, 's Gravesande championed a midway position. He was elected to membership in the Royal Society while visiting London.

[5] John Theophilus Desaguliers, 1683–1744. *Mathematical Elements of Natural Philosophy*, confirmed by experiments . . . translated into English by J.T.D. London, 1721; 6-th ed., improved by the author, 1747. Watt read this when he was fifteen, thus in about 1751. Desaguliers was held in high esteem by Newton, and was elected to the Royal Society.

The information about Watt's reading was taken from James Patrick Muirhead's *The Life of James Watt*, London, 1858, p. 22, 39, 64, 75, 83. Andrew Carnegie wrote a lively biography, *James Watt*, New York, 1905.

formity and parsimony, and points out that the scientist should be broad-minded enough to admit that substance, though he can never know anything about it, may have properties about which he can know nothing. This is to counter the theory that substance is the sum of observable qualities.

If we grant that Watt was impressed by this preface we may think of him as having inherited along with Hume the British tradition of empiricism. The portrait of Newton[6] which hung in his father's home and which perhaps indicated the direction of the sympathy of the family, was a symbol in another sense of the same legacy.

Now that we have looked at the common ground occupied by Hume and Watt shall we turn to what is a more intriguing consideration from the point of view of the effect of each Scottish thinker on history? We must infer that a critical difference of interpretation of the nature of empiricism itself separated Hume from Watt; and this difference, we shall find, exemplifies vividly the curious dual rôle which empiricism has played in the world of science ever since.

Had Watt been asked whether the iron, coal, fire and steam among which he dwelt were "appearances" he would in all probability have answered "No." "Appearances" are not genuinely real. The hardness which one feels when the hand comes in contact with iron, along with the feeling of warmth when one draws near burning coals, and the sound of the boiling water, pumping piston-rods and revolving wheels when one is in the neighborhood of a steam-engine are real in a sense, but not too real. Such qualities should not be confused with the actual hard substantial facts in the world of mines, blast-furnaces and cotton mills.

Hume on his own testimony recognized this same distinction when he stepped out of his study. But while in his arm-chair he saw the universe differently. Then the question whether iron and steel were analyzable without remainder into "appearances" would have brought an emphatic "Yes," although he would have preferred the word "impressions" to "appearances." That is, Hume while in meditative mood regarded the realm of sense impressions, memory images, images of the fancy, and feelings like hunger and joy as the only world. The other allegedly more real world of coal mines, blast-furnaces and cotton mills is a part of the panorama of psychical entities, is a tapestry the warp and woof of which are threads of consciousness.

Hume's quaint arm-chair speculation was the result of his taking seriously the dictum that all knowledge comes from observation. Suppose we consider the sentence: "Under normal atmospheric pressure water boils at 212 degrees Fahrenheit." This statement is commonly understood to mean what it says, an interpretation which we shall call loose; that is, it is an empirical sentence, but empirical only in a loose sense of empirical. For Hume, however, it would have had a stricter sense. He would have applied to it a hair-splitting literalness, and perhaps for most men would have seemed carping and obstinate. When we say that under normal atmospheric pressure water boils at 212 degrees we mean, according to Hume, that one pattern of sensations called fire, particular readings of the borometer and thermometer, and water at the point of boiling, is followed by another configuration of sensible data including those which we call boiling water. This is our meaning and it is all we know about the situation. Hume took with the ut-

[6] Muirhead, J. P., *op. cit.*, "Among the few articles of household decoration of which the humble mansion of Thomas Watt and his sons could boast, were portraits of John Napier . . . and of Sir Isaac Newton." p. 29.

most Scottish hard-headed literalness the idea that knowledge has its exclusive origin in observation. He refused to understand in such a sentence any meaning beyond what was capable of corroboration in the experience of an observer. For him, consequently, transcendent beings like matter, efficient causation, force and energy drop out of the picture.

Watt, however, along with Desaguliers, Newton and Galileo, understood by empiricism much the same as any practical mechanic or technical student actually dealing with machines and forces would have understood, and would still understand to-day. Machines for a person who handles them are set in motion by a very real force generated in the combustion of coal and the expansion of steam. They exist for the force which they get and give. Such men, if they have any thought of the theory of knowledge, are empiricists because empiricism is a common-sense attitude. They have learned through experience that the only practical way of discovering how forces behave and how they are to be harnessed, and how machines are to be improved and manipulated, is by careful observation over a long period, by experiment, testing, trial and error, and the rest of the battery of empirical methods.

Hume's empiricism, as one might anticipate, was the last stage of a blind alley. His "Treatise,"[7] as he quaintly wrote, was "dead born from the press." If you wish to emphasize the value of observation as a means of knowing you can go no further than to say that nothing exists, as far as you can know, save immediately observed data (patches of color, sounds, smells, etc.). In Hume's hands the empirical tradition, despite its beginnings in the laboratories of mechanics, suddenly became a metaphysical scheme suggesting, as Thomas Huxley once wrote, Buddhism. Such extreme empiricism is poor ground for action, especially for the sort of action upon which there is a premium in an industrial world growing by leaps and bounds.

The future lay with Watt.[8] To try to explain the origins of modern commerce and industry in terms of pre-Humian philosophical empiricism is, no doubt, to oversimplify grossly. The Medici, who patronized Galileo, were already merchant-capitalists on a vast scale, and part of Galileo's personal motivation was sympathy with the economic aims of commercial-minded rulers. He spent years, for instance, in the search for a way to determine longitude at sea—a clear case of business needs instigating research. It is also true, however, that Galileo's purest theoretical researches, his inquiry into the rate of acceleration of falling bodies, turned out to have incalculable value to investigators with the most practical of motives, the engineers. Thus one may say without exaggeration that from the beginning science proved an ally to the development of industry and commerce. This is the case more clearly with Watt, and in this sense one may affirm that the future lay with him. In his hands science became overwhelmingly powerful in the practical world.

Watt grasped the needs of his age. Others besides him could do this, including the business men, which accounts for the comparative ease with which he was able to form a partnership with the wealthy enterpriser Matthew Boulton after his experiments had caused the bankruptcy of an earlier backer. England was awaiting the mastery of a new

[7] *A Treatise of Human Nature: being An Attempt to introduce the experimental Method of Reasoning into Moral Subjects* . . . Book I. Of the Understanding. London, 1739. Note the words "experimental method" in this title. By "moral" is meant "mental" or "pertaining to mind."

[8] Even his name has become a common noun, the watt, which significantly is the name of the practical unit of power.

Watt was elected to the Royal Society in 1785, an honor which never fell to Hume.

brand of mechanical energy. Consider the plight of the coal mines in Cornwall. They had become important since the exhaustion of the forests for the supplying of fuel in the blast-furnaces of the iron industry; but unfortunately flooding had made them unworkable. Exploiters of steam before Watt: Savery with his Miner's Friend and Newcomen with his Atmospheric[9] had attacked this problem, but their pumps were hopelessly uneconomical. They pointed, nevertheless, in the right direction. Watt's first steam-engines were also pumps, and what the business men had shrewdly foreseen happened in little more than a decade: these improved pumps saved the mines. Another need for a prime-mover was in the rapidly growing textile industry, the leader of which, Sir Richard Arkwright, had patented a spinning frame. This was destined to change the once pastural England into a factory-nation as soon as a source of energy independent of geographical location (of water-falls, for instance) was harnessed. Watt's engines, now advanced beyond the pump stage and equipped with rotary motion (also his invention) so that they could drive machinery, filled this bill. England was ready for Watt. But this should not cause us to forget that he was a scientist, an heir of the tradition of genius flowing from Galileo, Gilbert, Boyle and Newton. When we say that his invention was a chief factor in ushering in the Industrial Revolution we are justified in adding that the scientific outlook loosely understood (interpreted not in the way of Hume) was a chief factor.

[9] Desaguliers, also, in 1721 set up a steam pump in his London home.

The moral of this sketch would be plainer if we expressed more succinctly the fortunate combination of interests, aside from the economic situation, which made science possible as a force. This would be in terms of the words "strict" and "loose." The scientists from Galileo to Watt failed to distinguish between the strict and loose scientific outlooks. They did not consider whether it was possible to have immediate empirical experience of matter and force; that is, directly to prove their existence by observation and experiment. Again they failed to consider whether there was empirical justification for their confining their attention to one area only of empirical data: size, figure, mass and motion, the qualities amenable to mathematical treatment. If they had been critical in these two respects, if they had turned the spotlight of their technical methods of operation upon the ideals guiding their choice of what should be accepted as real and as representative of the real, they would have come to the same impasse as did Hume. Instead, however, they pursued the indulgent course. They uncritically abided by the Cartesian mechanized reinterpretation of the old Aristotelian efficient cause and by the Democritean atoms, and they gave to shape and the other primary qualities a capacity for reflecting reality which they denied for instance to smell. Because of this loose thinking they transformed the world.

PROPAGANDA AND THE DEMOCRATIC STATE

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MASS beliefs are the most striking phenomena in modern civilization. To control them is the most important function in the state. Knowledge of even a few of the laws that govern the development of beliefs is highly desirable. The unhappy changes that have taken place in three great European countries evidence the close linkage of the welfare of a nation with the use or abuse of persuasion. Common elements may be detected in the methods employed in all three countries and in the course of the change in sentiment. In Russia, Italy and Germany hate was developed in the mass of opinion, against the established order. In Russia the theoretical object of the hatred was the industrial order, but there was a background of revolt against the autocratic rule of the Czars. In Italy the object of the revolt was the socialist worker domination of industry that had proven itself incompetent. Here again a large element in the emotion was a revival of the greatness of the Roman Empire. In Germany the object of hate was the Versailles treaty, especially the derogation of the dignity of the German people. Minor hates were toward the Jews and the government, both, it was alleged, because of blame for losing the war. Economic factors were not mentioned, although the general economic depression, following the war, inflation and later retrogression of industry was a contributory element, without doubt.

In each country, the movement gave power to a leader. In each instance the leader when in power forgot his beneficent intention and threw over all signs of a democratic control in politics. In varying degrees he took charge of the economic life of the community, expropriating many of the industries from former owners. The new leader did not hesitate to murder his opponents and in time many of his early supporters and to appropriate all the power and most of the wealth at the expense of both capital and labor. In no one of the three countries were the promises of a more liberal rule kept. The fine phrases that had served as slogans in the overthrow of the old régime were kept only as a sop to reduce the discontent of the ruled with the new order. In each instance the leader who won was a man with little that would mark him for the position. Lenin was one of many revolutionists who had fallen under the notice of the authorities and been compelled to go into exile. Mussolini was an editor and a leader of a socialist group, but he had no great following in politics.

Hitler was a man who seemed still less likely to attain leadership—an unsuccessful artist who seems to have earned a precarious livelihood by odd jobs of house painting after the war. There is some evidence that he is a hysteric. At least a member of the Heidelberg medical faculty was sent to a concentration camp for saying that Hitler escaped service in the first world war by hysterical blindness. Hitler himself gives confirmatory evidence in his speech comparing his hard life with Roosevelt's opulence. He states that he was blind for a time and recovered. Hysteria is one of the few causes of a blindness that may be recovered from spontaneously. To add to his handicaps Hitler was an Austrian and so a foreigner. Despite all, Hitler marched on to power. The prison sentence for the Munich attempted revolt gave a chance to write "Mein Kampf." His eloquence and

audacity accomplished the rest. He finally obtained, next to the communists, the largest number of votes in an election. Hindenburg feared the plan of von Schleicher to divide the East Prussian estates, one of which he held, and made Hitler chancellor. Once in power, Hitler abolished all but the form of the Reichstag and took complete power for himself. Even the army did not oppose the move, although he was repugnant to all their class and professional traditions. The methods by which a single man can dominate a nation offer a problem of the greatest interest. It can be considered in part as a phenomenon of the crowd in relation to a leader. From another aspect it indicates the type of proof that may be accepted by an audience or a wider group, especially of how far conviction is of what we call a rational character and how far it is dominated by emotion. Even if the analysis can not at present be complete, enumeration of some of the known factors are of value. Democracy depends upon a control of these forces. Domination of a nation by a single individual, even if he at first has the best of intentions, ultimately leads to the destruction of freedom.

All agree that a man in a group has a different character from the same man alone. The degrees of difference vary with the size of the group and the occasion. Le Bon asserted that a man in a crowd becomes as a man hypnotized. He loses his capacity for decision, his intelligence is reduced, he becomes more emotional, he feels rather than thinks. Even an audience under the control of emotional speakers may show some of these characteristics. Hitler in "Mein Kampf" asserts that the man in an audience is of a mental age of eight, that you can not reason with an audience, you can only arouse the emotions. A mob as it starts on an illegal errand such as a lynching, or any even minor riot shows the same tendency. Any idea that is suggested will lead to excesses that the same men in their sober moments would repudiate. At the least the man in the audience is too ready to believe what he hears. An illustration is Borah's statement a little before he died. He was asked if he had heard the President's speech on foreign policy on one occasion. He replied "No. I do not dare listen to Mr. Roosevelt. I can't trust myself not to believe him, and always regret it later."

One might urge that the orator who plays upon the crowd may also go into a sort of trance. Rauschnig, a careful observer of Hitler, made the statement that he could talk fluently only when he worked himself into an emotional condition allied to frenzy. When he was addressed casually on ordinary questions, he was reticent. He seemed to have difficulty in answering a question. When he desired to give an answer he seemed to go through an intentional process of developing an emotion. Then he gradually showed an intensity of response that was altogether beyond that appropriate to the size of his audience. He spoke as if another were speaking through him. A chance to analyze the character of the orator's state of possession would be valuable and should throw light upon several problems of the orator and the crowd. One can not charge every man addressing an audience with being in an even slightly abnormal condition, but as we have seen, there are indications that some are. Most speakers who are at all facile probably respond better when speaking to an audience than when alone and some do markedly better. The difference between such a mild stimulation and the frenzy-like state of Hitler is very great, probably is more than a difference in degree.

One can see exaggerations of this response to the crowd in individuals who are definitely insane. A man who had the background of a clergyman in a Protestant church and who later was a C.I.O. labor leader experienced an attack of circular insanity. In the excited

phase when presented to a class he began an eloquent oration or sermon on a religious topic. The tones were of the pulpit and the topic was religious rather than of the later labor phase of his career. The mental processes were not orderly, but the form was characteristic of the orator. Not too much should be made of this as an indication of the possible abnormality of the speaker in general. Any habitual activity is likely to be prominent in the activity of the insane. The presence of a group served to start the speaking reactions with full gusto, and they were carried through with complete assurance and with effectiveness of manner. That an insane man in a period of exaltation falls into the habitual response of the orator, does not prove that the orator is necessarily abnormal, but merely that even insanity is not incompatible with the speaking response.

The action of the speaker on the audience, and the general interaction of a man upon other men, is fundamental to the development of social life of all forms, including the economic. The action of the speaker on the audience is the best illustration, but the influence of the written word in press and in books and in recent years the influence of the radio is equally important. The use of words in moving mass opinion is propaganda. Propaganda depends upon the laws of social psychology or would if the laws of social psychology were fully known. The first law is that the mass to be impressed should be made or induced to transform itself into a crowd or a mob. It must be unified to the degree that all think, and still more, feel in unison. A criterion of this condition is hard to obtain. It seems not to be identical with intellectual approval, or at least less connected than one would think at first sight. In listening to an address man is only in part a rational being. Much more is he controlled by emotion, and the previous attitudes that he has built up.

Argument implies the use of facts and deductions from facts by accepted logical means to establish truth. Propaganda suggests that a conclusion that it is desired to establish is untrue or at least not quite above criticism. Propaganda is at best an argument by one in whom the speaker does not quite believe, and the term suggests that the methods of proof used are open to suspicion. One uses it of the political moves of an enemy in influencing neutral opinion or in seeking to undermine the loyalty of one's allies or one's own citizens. In a political campaign it is a not quite straightforward use of arguments, or the use of false statistics in establishing a point. It may involve fallacies, it is also used for arguments not demonstrably false in which emotion rather than fact dominates.

Justifiable argument, on the other hand, relies upon relating the conclusion that the speaker tries to establish to accepted and completely established principles. Sometimes, but that is rare, a statement may refer to a definite fact that can be established by witnesses. Most argument relies upon mentioning more or less closely related facts or principles that are known to or accepted by the person to be convinced and showing him that the conclusion to be established is of the same class or follows directly from the facts or principles that are mentioned and accepted. In general it may be asserted that belief comes from a reaction of what one already knows upon any new statement. When there is consistency between past knowledge and the assertion that is proposed for acceptance, belief develops; when the new conclusion suggested is not in harmony with what is already known, it is rejected. Argument consists in bringing to the fore the phases of experience that are in harmony with the conclusion the pleader desires to have the audience accept. If it succeeds belief spreads from the accepted to the new and that

too is believed. We need not go into the details of the theory of proof. Proof by this means appears to constitute the essential factor in what we ordinarily know as logical proof.

However, much of the conviction attained in any discussion is not to be referred to pure transfer of belief from the already accepted to the proposition to be established. Much even in formal logic syllogisms depends upon indirect influences, upon what Woodworth has called halo effects. Many of the recognized fallacies of logic can be referred to the influence of word or propositions that are implied but not stated by the words. One confuses some with all. One takes words suggested by the words used for the words themselves. The intellectual processes are themselves dependent upon influences that are not supposed to determine the decision to be made.

More striking is it that factors that would be classed as emotional rather than intellectual exert an important influence on the decision. Evidence for this has accumulated both from common observation and from tests of different kinds. One may quote Hitler for the results of a general impression. He, among living men, has made most use of propaganda for political purpose and has been most frank and cynical in stating his conclusions. Hitler asserts over and over that what counts with an audience is not reason but emotion. He reiterates that the discussions of the social democrats who dominated Germany for a dozen years before he came to power were entirely of a factual, rational character. The conclusions that they favored were stated with logical precision and based upon facts established fully by statistical methods, but they failed to have any influence because they were entirely lacking in emotional appeal. Similar statements are made by Chen as a result of experimental studies on changes in student opinion on the Manchurian question under the influence of factual as compared with emotional appeals. He found that attitudes as measured by replies to a questionnaire were changed markedly more by an emotional appeal than by the factual statements.

Possibly the most direct evidence was an experiment by Lund on the relation between the pleasantness of a proposition and the tendency to believe it. Lund's method was to ask students in different universities to grade a series of propositions first for their pleasantness and then as to the willingness to accept them as true. The propositions covered a wide range in religion, politics and ethics. When he plotted a curve of degree of pleasantness and compared it with a curve of the acceptance as true of the same proposition, he found that the two curves overlapped in a large extent of their course. The coefficient of correlation between the pleasure aroused by a proposition and the amount of belief showed a coefficient of correlation of more than +.80, a very significant correspondence. If this be taken as fully justified it would mean that wishful thinking is the rule rather than the exception. That one thinks what would be agreeable and then accepts the agreeable as true.

Evidence is also accumulated that of the feeling or emotional processes, hate or anger is more effective than admiration or love in the arousal of belief and is especially effective in arousing to action as a result of belief. Again we can turn to Hitler for the practical illustration, most striking in recent times. Hitler shows in "Mein Kampf" that a constant reiteration of reasons for hating another group or a cause arouses the hearers of a group against them. Exciting hates in this way will unite the group that hates into a common mass that may make them think and act together. Hitler aroused his group and developed the national socialist party by expressing the common resentment of the German people against the Versailles treaty. This was associated with regret over the

lost war, the memories of the sufferings during the war, the economic decline of Germany that followed the war and the inflation which was permitted by the parties that governed Germany in the years that followed. The whole series of events developed a feeling of inferiority and uncertainty in the German people, directly in contrast to the overbearing attitude in the imperial period. It was all the more disheartening because of the previous exaltation.

A more personal hatred was turned towards the Jews. This was again a case of increasing a race prejudice that was fairly wide-spread in Germany. It was partly a holdover from medieval times when it was expressed by isolation in the ghetto, partly it was rearoused through competition with the Gallician and other Jews who migrated to Germany from the more eastern Slavic countries after the war. This hatred was tied to the resentment over the war results with the statement that the Jews are responsible for losing the war. Of course the reasons assigned were not adequate for proof. This again harmonizes with Hitler's general thesis that the hearer is really moved by emotion, not by evidence. Tying responsibility for losing the war to the Jew was an added stimulus to hatred towards him. The weakness of the evidence was considered by no one except the Jew himself and his friends. Apology for him did not count in connection with Hitler's purpose. Any man who wants to advance a cause or form a party finds it very much more effective to turn the hatred of the group to a man they want to oppose than to praise the man or cause they seek to favor. Societies and groups are held together more firmly by common hates than by common loyalties or loves.

Study of propaganda in any form bears this out. Lasswell and Blumenstock have given a detailed account of the methods used by communists in Chicago during the early years of the depression in which the use of hate comes out very clearly. This, like Hitler's campaign, was definitely an attempt to induce a revolution in America of the Russian pattern. In all the maneuvers, emphasis was placed upon the imagined responsibility of definite individuals for the deprivations of the people. No instances in their appeals are found in which they state that the Russian worker was in a better condition. The facts would not support that statement. For propagandists that would be no bar to the statement. All banners and slogans referred merely to the difficulties of the lower income groups in America with the charge that the bosses are responsible. Much use was made of the words starvation, bloody bosses, oppression, police brutality, all designed to raise the emotions of pity for the victims and then hate for the individuals who are assumed to be responsible. There was no demonstration that the connection asserted really existed, and no discussion of a possible remedy. The emotion is essential. Coupled with the hatred of the present state is the assumption that a change in government or the destruction of the capitalist system will at once prove a cure-all for the difficulties.

Laying the Basis for Belief or Attitudes

We have said that proof in dealing with an audience or in a treatise is a process of pointing out the aspects of the position that you desire to establish that harmonize with the fundamental beliefs of the audience or with experiences common to all. Obviously the next question that arises is how did the fundamental principles that are used in arguments themselves become established. Or from the practical side, if you desire to convert a community or a nation, how can you inculcate the basic axioms that are to be used in later arguments? It should be said that political and economic matters are involved in our discussion, although analysis might show that many so-called rational and moral

principles have been inculcated in very much the same way. At any given time there is a body of beliefs stated in aphorisms or formulae that can be counted on to be accepted in the great social body. Some of them embody common experience. We can leave out the groups that depend upon verified scientific observation and its laws, although a sceptic who observes the changes in scientific formulations from year to year or from generation to generation may question whether all that is taught as science is free from the domination of tradition.

Establishing these principles is more fundamental than the mere arguments of the orator, in fact the effectiveness of the orator depends upon them. One can trace the principles by studying changes in the beliefs of social groups as they occur spontaneously or by the intent of the leaders. Psychologists have also made a few studies of short range changes in sentiments in children and students from seeing movies or from stories and arguments. Both methods of approach leave much to be desired alone, but the results from each confirm the other and check with common observation. The results indicate that what is accepted is a matter in part of mere repetition, in part they are dependent upon the social group by whom the statements are made, in part they are dependent upon purely emotional elements. They may also have a pragmatic test, they work or seem to work, although it is surprising how many statements and practices have been accepted as true through the ages that did not work and might easily be seen not to have worked—the use of charms for cures or even bleedings and similar surgical practices. Except under carefully controlled measurements and records, the measure of success has been very little applied and much that obviously is not effective continues to be believed.

Tracing the growth of beliefs is a fascinating subject and should offer many rewards in understanding the completed mass of doctrines of a community large or small. The radical thinkers in America assert that the school books are responsible for our economic faith and would change the books to establish a new faith. They assert that the founding fathers were men of means and in consequence assumed the sacredness of property, the desirability of frugality and honesty and the right of an owner or manager to direct his own business. Coupled with these are aphorisms about the American way of life that are familiar to all, but that might be difficult to enumerate from their very familiarity. For this the liberal group would substitute the familiar Marxian principles that the framers of the constitution were grasping members of the exploiting classes and that the constitution and the laws based upon it were framed for the express purpose of keeping the laboring classes in subjection. These principles are said by the American Legion to be embodied in widely used texts of social science. The charge is that the author has changed fundamental statements to give a communist bias to the teachings.

That school textbooks are important in establishing certain beliefs as axioms is obvious. Each revolution revises the texts in the light of its doctrines. It is said the primary reader in Mexico introduced by the revolutionary government had a picture of a Ford assembly line with men with whips standing over the workers. When a Russian first reader was adopted for use in an American university certain pages were carefully cut out. It is to be assumed that it was to prevent the students from knowing what the propaganda of the soviet was, rather than to avoid converting them to the Stalin philosophy. To write the elementary textbooks of a nation would exert an influence, possibly a determining influence upon the social axioms of that nation.

In general it seems that the processes by which attitudes are developed or principles that shall be accepted in a com-

munity are established as axioms can be traced to a few relatively simple procedures. One of the easiest is persistent repetition, especially by a respected source. Many of the accepted moral precepts are established in the family by hearing them over and over, with an occasional punishment for failure to follow them. The parents lend their authority to the repetition. The church and school add their influence when the child is older. On the whole it is repetition in an atmosphere for well wishing that gives strength to the admonition.

In addition there are many obviously emotional elements. We have mentioned close correlation between pleasure and belief. A principle that is pleasant to the listener can be accepted much more quickly than one that is not. The bolshevist statement that only the man without resources deserves any place in the state won acclaim from the vast majority who belonged to that class. These men would not have accorded acceptance to a doctrine that hailed the importance of the man of high intelligence or the minor capitalists of a community. The German is willing to accept the belief that all Aryans are superior. It is pleasant to be a superman. The boys of fifteen or so to whom Hitler gave brown shirts and told that they were the hope of the nation and that they and the nation would prosper together, believed the statement in part because it was pleasant to believe.

The play upon hate is equally strong. To believe that the owner of property who may seem so arrogant is really a man who has profited at the expense of all like himself raised a burn in the breast of the Russian that prepared him to murder and loot with an assurance of virtue that mere belief in his own importance would not have justified. When glorification of himself and hate of the possible opponent are active, the development of beliefs that may become the axioms of national or group thinking is easy. We see them in the patriotic assumptions of all countries and we can see how easy they are to transform in the development of the Russian and Nazi movements. In both many of the doctrines that for ages have been accepted by the larger group were overthrown in a few years by studied propaganda. The social and moral axioms can be changed more readily in the young as can be seen in the black shirt fascist groups and brown shirts of Hitler, but the Russian revolution worked mainly with adults. All ages are susceptible to strong influences that work upon the individuals in an accepted milieu.

This is little more than a sketch of what needs to be done if we are to understand the forces that drive modern society. The basis for the control of a social group must begin by developing axioms of what is right and wrong. The simplest way to get them accepted is by repetitions of phrases and of acts that embody them. Those will be accepted that please the group. Wishful thinking is fundamental to the establishment of attitudes. These require a long time to establish and the instruction must begin at an early age if it is to be effective. Canadian officers in control of a German prison camp in Ontario say that men in their late teens and early twenties are ardent Nazis, the older men are sceptical. Expectation of personal advantage and hatred for the men who oppose are essential to give warmth to the axioms.

When these principles or axioms are established by repetition in word and deed, they become the foundation for the work of the orator. Reference to them wakens belief for new propositions that can be shown to harmonize with them. They furnish the unseen basis of later social movements. Morale comes to a group when it accepts a mass of common beliefs or emotional axioms and the group can be roused to enthusiasm for expected results, or can be roused to hatred of the opposing group or the upholders of other principles.

CAN SCIENCE ENTER THE SOCIETAL RANGE?

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THIS question demands, for its useful consideration, a ruthless clearing of the ground; it must be realized once and for all that as yet nothing worthy of the name of science exists within the societal range. Every candid student knows that "sociology" languishes in a well-deserved disrepute. A not unfriendly, though somewhat patronizing judgment[1] avers that it covers whatever is left over by economics and political science. There is ample warrant for dropping the term "sociology," had the Greek any other available term to offer. For a name should allocate and draw boundaries. If one is studying petrology, he knows what he is doing and so does everybody else. He does not, and they do not, when he professes the "science of the social."

But let us accept this unhappy situation as, at any rate for the present, irremediable, and take refuge, with Pareto, in letting names go hang and attending to things.

That we sorely need a science of society upon which to rest in our effort to get along together, is evident even to a fool. Nothing has happened in over sixty years to invalidate the chapter on that need in Spencer's "Study of Sociology."[2] It is always the same old, the same pressing, the same unfulfilled need. Supposing men had, to govern their social dealings, anything remotely similar to what they possess, to guide their enterprises in the range of material culture, in the science of chemistry—what a relief of confusion and error would the race experience! As it is there is nothing much to restrain mankind from acclaiming and following, over and over again, and always with fresh hope, any social perpetual-motion fanatic or gabbling medicine-man. Men remain credulous, especially when they are in trouble, because there is no touchstone upon which to rub what is urged upon them. There is need for such a touchstone in order to become critical and discriminating. And the only reliable stone is the one available, and also in daily and unquestioned use in the material realm, namely, science.

The demand for a genuine science of society is rooted in two considerations: first, men must always struggle to live; and, second, their struggle must always be pursued in association with their fellows.

However philosophically debatable the question whether life is worth living, it is a safe bet that the issue of the argument will never be wholesale suicide. "The first task of life is to live," and nature has implanted an instinct, in men as in animals, to see that the task is not evaded. That fact is not to be set aside because now and then some individual chooses death in preference to some other ill that seems to him greater. When death is risked, it is usually in the hope of life. Men are going on trying to keep alive, just as they have done from the outset.

And they are going to do so together, not apart. Whether they have a "herd-instinct" or whether the world is not big enough for a billion Crusoes, so that men have to live in association whether or not they want to, the fact of associa-

[1] A. A. Berle, reviewing T. Arnold's "Symbols of Government," in *Yale Review*, summer number, 1936.

[2] Published in 1874, chapter I.

tion remains. The human effort to live is going to be pursued conjointly.

Beings who are going to keep on trying to live, and to live in society, must likewise keep on seeking the best way to do so. They need to know how to live in association. History records an endless series of tentatives in the *how* of living together. Some of them have failed and been eliminated promptly. Others have persisted. The only generality we can be sure of is that the issue has been decided, in all cases, by experience. That is why tested experience is the surest guide there is.

The verdict of experience may be rendered in terse, sharp and compelling terms, or it may be involved, cryptic and ambiguous. A number of tribesmen eat of some deadly fungus and all who have eaten die; then the terrified rest clap a taboo upon that outreaching toward a wider food-supply. Candles are speedily discarded in favor of oil-lamps, lamps for gas-jets, jets for electric bulbs. A little experience, when crystal-clear, convinces as to which are best for living. The appeal is to "common sense."

But not all cases are so plain. An epidemic following the appearance of something unfamiliar—say, a comet—has often been attributed to the heavenly visitor; the accuracy of the white man's rifle has been accounted for by magic. We think such attributions childish, knowing from experience that smallpox is independent of astronomical happenings, and all about rifling, sighting and wind-gauging. That is because we have a great deal of accumulated experience to go on that simpler civilization has not acquired, recorded and worked over.

Evidently "native common sense" can go some considerable way in enabling mankind to profit by experience, but by no means the whole distance. It is more at home in dealing with things—things that can be handled, weighed, measured, cut up, pulverized or destroyed—inanimate things, plants and animals—in the main, also, things that stay the same, as iron always remains iron or an onion an onion, in distinction from *varium et mutabile femina* or the religion that needs, we are told, a new definition once in so often or the chameleon-like "right" or "justice." Can "plain common sense" pass upon such proposed innovations as birth control, Christian Science, the lottery, socialism, the New Deal? Evidently not.

In dealing even with material things, "native common sense" has been forced to refine itself. It has become what Huxley said science is: "trained and organized common sense." In refining itself into science, common sense has had to drop a good many childish tricks, along with the acquiring of a deal of self-discipline, meanwhile preserving and developing the sterling traits of its character. It has had to renounce wishful thinking, metaphysical day-dreaming and religious dogma, and get down to brass tacks in the cultivation of its affinity for and acquaintance with experience, also in learning how to handle facts of experience so as to evoke from them the maximum quantity and quality of knowledge. In the laboratory it has developed an efficient instrument of experimentation, which is the staging of experience under varying conditions. It has produced the expert. Let no one fail to realize that experience, experiment and expert are blood-brothers, all deriving their being from the same primeval common sense.

Science is not science unless it "makes sense," and nothing nonsensical can be scientific. "Native common sense" usually senses the sense in what science, its refined progeny, does, just as it speedily comes to harbor contempt for the results of pseudoscience. It is hopeful to see the "common man" put his life and money upon the reliability of the chemist while he jeers at the emo-

tional utopian—after a time, at least, and even though he has cheered for a charlatan and followed him awhile.

Let us look for a moment at the likeness in method between common sense and science. Both rest upon experience as the one sure basis. Both gather facts of experience, compare and weigh them, and out of them formulate rules of action. Both forecast the future on the basis of anticipated recurrence, that is, by expecting things to recur about as they have occurred, and not otherwise—conditions remaining similar. The only real difference is that common sense acts more casually, with less premeditation and preparation, more sketchily, more forgetfully, where its refined version has been trained and organized and recorded and systematized. But the essential processes are the same in both. Among the practices they have in common is the immediate rejection of any course not verified, or no longer verifiable, by experience.

Verification on experience is much easier, speedier and more compelling in some ranges of man's life in society than in others. That is why, where they have been dealing with material culture, men have worked out into science, while still far short of science in their handling of the institutions of society—property, government, religion, marriage and the family. Though the line of distinction between natural science and social science is not always sharp, as types the two are readily recognizable and distinguishable, and may be set in contrast without doing any violence to the truth.

In the societal range, as well as in the physical, there has prevailed the same necessity of trying to live on—instead of committing group-suicide. Men have to keep on trying; and they want to waste as little time and to suffer as little from dashing into blind alleys as possible. There can be no dissent about that. They have never desired to make mistakes or to act nonsensically or to sin or to do anything else except what is expedient. They want good social experts so ardently that they have deified many a quack and scalawag who was lucky enough to profit by some coincidence between his promises and the course of events.

Always, in social living, "something has got to be done," and right away. Men are readily persuaded of this necessity, and it is often real. This was once the case in the now accredited sciences. The medicine-doctor sweated the evil spirit out of a sick man, so that he got well. "I work miracles, and by Gott! dey come off, too." All the sciences have had to make their way in the face of slapdash stabs, wholly irrational in theory, that seemed to bring about results—and sometimes accidentally did, by reason of some latent virtue, irrelevant to theory, that resided in them. Science had to put up with such coincidences on the surface of things, working away the while upon the solid and rational foundation of truly verified experience.

In default of guiding principles, random tentatives have to be made until the substructure of principles and laws can be laid. It must be so, in the social range, for a long time yet. No fault is here found with the tentatives cautiously, or even incautiously, launched by those who, on the firing line, have been convinced that they must do something on the basis of native common sense, buttressed, perhaps, by prayer. They have not been able to wait for the training process. There is no blame for any of these enterprises, whether failures or not, so long as their initiators have used all the knowledge available, and disingenuously.

But any person of sense will agree with the foregoing contention, that if we had a science of society even approximating from afar off the science of chemistry,

we should be so much better off that this world would be indeed almost a new one. Why not try, then, to have such a science, instead of either drooping in dejection or stabbing about aimlessly in an ecstasy of untrustworthy noble intentions?

If we are going to try to have a science of society, how are we to go about it? If you note that a certain player generally wins, you want to learn how he does it, do you not? Let it first be sadly but honestly recognized that we may never attain a genuine science within the societal range. There are for us many lions in the path. But there is only the one path, lions or not, that has ever led to the kind of trained and organized common sense in which people show confidence—by act, if not by word, and even when they repudiate it in their words. It is to be noted that even the *precieux* who daintily sniffs at science as a materialistic, vulgar, crawling thing, yet sends speedily for the doctor when he is ill. He even pounds out his fastidious tremors on a typewriter that would not have been except for the sweating miner, the soiled artisan and the low-minded inventor, all henchmen of science.

There is, I say, only one road that has ever led to science. It is the part of sense to take that road. The way to get another science is to learn how the ones we have were got, and then duplicate the process as we can. There is no sense in any other procedure—that is, if we want a genuine science. If we are content to go on with the wishful thinking, intuition, introspection, logic-grinding and thin speculation that have characterized the bulk of existing treatises on society, that is another matter. In that direction lies the chance to maintain for "sociology" its present reputation for triviality, emptiness and pretentious unreliability.

Any one who wants to participate in developing a genuine science of society must steel his soul to renunciation. He is going to see no startling results within his lifetime. He is not destined to attain acclaim. He is like the caisson-builder laboring, down there under the surface, at laying solid foundations for piers that may some time rise—that will assuredly not stand, if they do rise, unless the substructure is arduously, honestly and conscientiously laid.

Pareto warns that the student of society must not be in a hurry about practical results. What he is advocating is, in a word, an austere, detached attention to the development of a pure science. Any such advice can never be popular, for it has never yet broken over men's minds that pure science is the most practical thing in the world. Scientific theorizing, pregnant with eventual benefits, is still confused with the speculation, the intuition and the yearning, just as scientific confidence in anticipated recurrence is identified with faith in divination or revelation. Many another besides Mr. Bryan is totally in the dark as regards the distinction between an hypothesis and a guess—the latter being the former minus data. Scientists of note have promoted this misapprehension by pontificating about matters quite outside the orbits of their special knowledge, thus betraying science to enemies who eagerly welcome and flatter antagonists who are corruptible by a cheap bribe of publicity.

If this generation does not need a science of society, no generation in the world's history has ever needed it. I shall not seek to labor the point in this era of big medicine. I shall merely suggest once again the relief and solace that all the nations would experience could they have recourse, in their welter of uncertainty, conflicting counsel, apprehension and despair, to a universally recognized set of verified sequences and laws such as that possessed by the laboratory sciences. And I do not despair of

the eventual attainment of something of the sort, comparable in spirit if not in perfection of technique, providing that enough devoted young men are led in the present and future to renounce acclaim as the begetters of bright ideas, nostrums and utopias in favor of a long-range program of obscure toil in building upon the solid under-structure of verified experience. "Hasty conclusion easy to make, like hole in water."

I may have been unduly discouraging in citing the laboratory sciences as models for the social sciences. It may well be that their techniques can never be duplicated within the societal range. Let me alter my formula: if mankind had a science even remotely comparable in its rigor and laws to other natural sciences than those of the laboratory—say, meteorology—the millennium would be many a parasang nearer. For these less exact disciplines have, at any rate, one element in common with the strictest sciences, namely, the scientific attitude.

For one thing, they remain unemotional. The meteorologist does not faint away in disillusionment and despair because a storm is indicated when he prefers fair weather. He coolly observes, then verifies and records his observations, without either tears or hosannas. He does not propose to change the nature of the weather (as some social experts propose to change human nature), but only to know about it. His personal wishes in the matter form no factor in his forecasts. He remains detached, dispassionate, objective. He is a weather-observer, not a rain-doctor. He has no rattle, no jargon, no persuasive oratory. He makes no passes.

If the student of social phenomena could do no more than assume that kind of attitude until it becomes with him a settled habit, he would have made a mighty stride ahead. If he finds the laboratory technique beyond him, as it probably always will be, but yet can qualify to take his place in the company of the biologist or geologist, without causing them to draw away as from contamination, he will be scientist enough for earthly purposes.

The first thing to do is to get the materials for the substructure together. That is what many an obscure student was doing prior to Darwin's architectural feat. Few of his forerunning contributors, without whose labors he could not have built his superstructure, had even the remotest idea of the general bearing of what they were about. Somebody became interested in pigeons. He thought, talked and lived pigeons, counted the feathers in their tails, recorded every minute detail he had lovingly observed, sent his results to some pigeon-fanciers' journal, and died. Then, in the fullness of time, along came the man with the synthesizing mind, endowed also with a colossal industry. He grasped and put together the toilsome observations of the pigeon-lover, the horticulturist, the entomologist, and expressed from a mass of verified experience an endlessly enlightening theory of adjustment. In some such manner, and in no other, there may sometime evolve a true science of society. It will never come by "thinking things out." That is the way to get a product resembling astrology or alchemy, the product which we actually have, and which is no credit to us. A science can not be "thought out." It must be worked out. This is no precept of "methodology." It is a piece of common sense.

Justice Cardozo has stated the case of the whole science of society in what he says of law: "Law is not an exact science. There the matter ends, if we are willing there to end it. Exactness may be impossible, but it is not enough to cause the mind to acquiesce in incoherence."

ANIMAL POPULATION CYCLES

By Dr. W. C. ALLEE

PROFESSOR OF ZOOLOGY, UNIVERSITY OF CHICAGO

ELTON'S monographic study[1] of populations of mouse-like rodents and their ecological associates would be noteworthy under any conditions; when considered as a contribution from war-time England and published there in 1942, it becomes downright impressive. While the major emphasis is on population study as such, the possible economic importance is never far below the surface. In the grain fields of Europe, the devastations produced by voles and mice often assume high economic importance; hence the study is not unrelated to "war research." In fact, in 1939 the whole organization for the study of animal populations which the author had built up was turned to the protection of food from rodents as a phase of the defense of Britain.

The pattern of treatment in the book is readily described. The first fifth is devoted to setting out the scale of the problems of populations of field mice in relation to European human affairs. This is an ecological problem which centers in the increase and decrease of population density. Research on the European continent has as yet done little to unravel the factors which underlie the more-or-less periodic increases in population density of these rodents, and the factors which produce the recurrent decreases have been partially concealed by attempted control measures. The effects produced by efforts directed towards population control have not been adequately described and hence defy analysis. One feature does stand out: whatever is or is not done by man, there is a natural termination to each period of abundance. The chapter devoted to Russian research on the ecology of animal populations is particularly useful not only because the intense activity of their scientists and the scope of their research program match the continental size of the Soviet Union but also because the published results are so largely a closed book to most scholars.

The author then gives a one-chapter survey of conditions elsewhere, especially in Australia and temperate North America where, despite the use of poison bait, human control measures are said to have been even more negligible in effect and, in North America, natural predators have been more important than in Europe. There follows an analysis of two vole plagues in Great Britain in which there was a minimum of human interference. These are described in some detail together with a rather full outline of the developing research program on the dynamics of populations of mice which centers about Elton's laboratory at Oxford.

The remaining 60 per cent. of the book is devoted to some of the animal populations of more northern lands. There is a condensed account of the much-discussed lemming cycles in Scandinavia and finally the last half of the book is taken up with wild-life cycles in northern Labrador. Here, attention often shifts for chapters at a time away from the mouse-like rodents to arctic and colored foxes and other aspects of the population problem. Also the tempo of the book changes; the treatment is more detailed and frequently tedious for the general reader. These slower moving chapters become important source mate-

[1] *Voles, Mice and Lemmings; Problems in Population Dynamics.* Charles Elton. Illustrated. 496 pp. June, 1942. $10.00. Oxford University Press.

rial for the special student. The data center about fur returns and the reports of fur traders. The pitfalls inherent in such sources are outlined with care, after which an attempt is made to make the data carry a full load of interpretative analysis.

The discussion of cycles of abundance lies near the heart of the whole book. One notable feature is Elton's rejection of the 11+ year sun-spot cycle in connection with cycles of abundance of certain animals. A few quotations will give needed perspective. In 1924 (*Brit. Jour. Exp. Biol.*, Vol. II, p. 133) Elton said: "I shall attempt to show that the 10 to 11-year period of the rabbit may be due primarily to the 11-year period in the sun." And later in the same article (pp. 138–139), "If we allow for the irregularity in 1905, the rabbit period agrees very well with that of the sunspots: *i.e.*, omitting the one in 1905, the average period for rabbits between 1845 and 1914 is 11.5. But the 1914 one should have been in 1912, and this brings the average to 11.1, which is about that of the sun-spots (=11.2)."

In his excellent small text-book, "Animal Ecology" (1927, p. 130), Elton continued: "The chief cause of fluctuations in animal numbers is the instability of the environment. The climate of most countries is always varying, in some cases regularly—as in the case of the eleven-year cycles in temperature and the frequency of tropical cyclones associated with the sun-spot cycle." In the present book (p. 160), the conclusion is: "I do not intend to go very deeply here into this theory about the sun-spots. There can be little doubt that it is wrong. . . . The chief point is that the biological rhythm is slightly shorter than that of the sun-spots, and long series of fur returns shows that the two cycles pass right out of phase. . . . Incidentally, it is a pity that several text book writers have quoted as a fact the sun-spot explanation of the Canadian forest cycle, which was explicitly put forward as a hypothesis to be tested by further research."

Elton still retains the possibility of an extra-mundane origin of these cycles of abundance. With regard to the lemming fluctuations in Scandinavia, whose suggested periodicity is three to four years, he concludes (p. 230): "So we are left, as with the British cycle, with a good many hints of some great cosmic oscillation, expressing itself in periodic upheavals in the biotic community, but we still lack the full key to the problem." One good reason for this lack is the absence of any well-established physical cycle with a similar periodicity.

The basic tables are arranged throughout the book to bring out evidence of periodic tendencies in population density. The text frequently summarizes the intervals between peaks of abundance and gives a mean value which is apparently taken seriously. The average length of the lemming-fox cycle in Northern Labrador is repeatedly given as approximating four years. One listing taken at random, that for colored fox skins traded in Ungava (p. 423), has intervals of "3, 3, 8, 3, 3, 2, 6, 4 or 5, 5 or 4, 3, 4, and 5: that is 12 cycles in 50 years, a crude average of 4.17. If we average all but the long cycle of eight years, the result is 3.8 or exactly the same as for the arctic fox." One may be pardoned, perhaps, for regarding such averages with skepticism particularly when we read in another connection (p. 325): "If the peak years are accepted to be 1921, 1925, 1927, 1931 and 1934 (the last is substantially confirmed by reports of a falling-off in 1935, though I have not the actual figure), they give a period sequence of 4, 2, 4, 3. If 1926 was not really a minimum, the sequence is 4, 6, 3. Either involves a reversal of phase in the four-year cycle such as happened in the nineties." The previous "reversal

of phase" is described on page 270 where the observed and hypothetical four-year periodicities came into complete opposition.

As an interested onlooker of the study of population fluctuations in nature, with the background of having read recently rather extensively concerning climatic and population cycles, it seems to me to be much more helpful at present to accept the variations in length of these swings in abundance as being an inherent, integral part of the phenomenon. They always occur where the records run for many years and are usually observed in shorter series. Such irregularities are common in biological phenomena that are essentially more simple than are fluctuations of population densities in nature. The more I consider the situation, at second or third hand to be sure, the more defensible appears the suggestion that these recurring, sometimes dramatic, swings in population density are an expression primarily of interlocking factors inherent in the loosely integrated population. This view does not imply an absence of effect by the physical environment, which, for that matter, may also show shifts in the length of a given cycle, but it does suggest that the physical environment plays a more remote subsidiary role. If this suggestion is accepted as a working hypothesis, the implication is that the lack of a close balance in population numbers, year after year, results primarily from the biotic relations within the population in question and between it and other populations of plants and animals with which it is associated, rather than the oscillations being the result of some imposed cosmic periodicity. If we can accept the irregularities as an inherent part of the phenomena at hand, rather than struggling, consciously or unconsciously, to fit the data into a periodicity of given average length, I believe we will be better prepared to make needed advances in the solution of these complex, but highly important population problems.

The wealth of tabular material allows the reader of the current volume a much better chance of evaluating the reality of correlations between cycles of abundance of different species than is possible when the basic data are given solely, or mainly, in small-scale graphs. The lack of statistical tests of the validity of proposed interpretations and correlations is a marked technical weakness despite the fact that many of the suggested correlations are shown in tabular form such that it is easy to make an informal estimate of their reality.

It never seems quite fair for a reviewer to mention small errors of proofreading or otherwise, unless they are characteristic of the book. The present volume is remarkably free from such, hence the statement (p. 110) that Mount Rainier is in New York State is all the more surprising. North Americans know better and, I presume, no one else cares.

Elton's stimulating and valuable study grew out of the work, ideas and records of the Oxford Bureau of Animal Populations, of which he is the capable moving spirit. Their archives contain abstracts of obscure and fugitive writings and they have access to the extensive records of the fur trading companies and missions of the Canadian Northeast. The important, pioneering efforts of this organization are supported in part by Oxford University. Initial support from the New York Zoological Society is acknowledged. The financial aid has come mainly from British sources including the Royal Society, the Forestry Commission and the Agricultural Research Council.

Despite the emphasis on cycles of abundance, the recurring theme of the book is the lack of information about

even the more elementary aspects of many of these problems. As Elton emphasizes, we do not know, for example, the actual population densities with which we have to deal. We do not know whether variation in rate of reproduction or in mortality plays the more important role in producing fluctuations in numbers. We do know that both may be important but we do not know the extent to which the two are interlocked. The need for the presence of trained ecologists on the spot in the rodent-ridden fields and pastures of France and in the northern fur country is emphasized. The need for the development of adequate knowledge of rodent diseases in nature and their correlation with human health problems is stressed. The number of furs that can be safely taken over a period of years, the amount of emigration and the distances covered, the interlocking relations between the size of the populations of lemmings, diseases of foxes and of load-pulling dogs, these are only a few of the points concerning which ignorance is stressed. "All [such] population research is tedious and requires a five- or ten-year run if new techniques are to be evolved that will produce safe results." Many of the problems can be brought into the laboratory for experimental analysis under controlled conditions; others can be successfully attacked only in the field.

Finally, "it is to be hoped that the reader of this book will by now have seen that we stand on the near shore of an ocean larger than any that Columbus explored, in which we can at present discern only a few islands rising out of the mist. Let us hope that wise governments [and other institutions] will train navigators and equip them to explore more closely the Islands of Vole, Mouse and Lemming and that they will do so not only in order to round Cape Fox and cross Dog Deep, but with some idea of understanding, not for power alone, but on account of its own wildness and interest and beauty, the unstable fabric of the living cosmos."

TRAVEL TO THE NATIONAL PARK AREAS

ALTHOUGH the National Park Service is accustomed to reporting large annual increases in travel, this year's figures show a decrease of 30 per cent. from last year, and travel for the month of June, 1942, as compared to June, 1941, showed a 50 per cent. decrease. However, an impressive total of approximately 16,030,000 visitors, including an estimated 650,000 members of the armed forces, visited the Federal park areas between July 1, 1941, and June 30, 1942, approximately 4,000,000 of whom were visitors after December, 1941. The rubber and gasoline shortages, the need of conserving transportation equipment for use by the military and war agencies and the limited vacations of workers in war industries made advisable the curtailment of promotion of park attendance not only by the National Park Service but also to a large extent by the park operators. Two meetings of representatives of the park operators were held with the director after the declaration of war. In so far as was consistent with the changing war program and the position taken by higher authority, it was agreed that the parks would remain open and public-service facilities would be made available to provide accommodations for the people who are able to visit the parks. Special reduced rates were continued in effect for members of the armed forces. The park superintendents were delegated authority to adjust rates and services to meet the rapidly changing war conditions.—*From the "Annual Report of the Director" of the United States National Park Service.*

BOOKS ON SCIENCE

GROWTH AND PATTERN IN THE BIOLOGICAL WORLD[1]

AGAINST parochialism in science, especially in biology, there is no more potent antidote than D'Arcy Thompson's, "On Growth and Form." In the second edition of this atmospheric masterpiece, physicists and mathematicians will again find their labors bearing new fruits in nôvel settings, while engineers, if not depressed by the anticipations of dinosaurs, will detect in the vertebrate skeleton either the realization of their best structural ideas or else suggestions for new ones. However, for biologists by and large "On Growth and Form," though disconcerting, should be intensely luminous and required reading. Even a layman dipping here and there is certain to find some weighty or delightful titbit in his net.

Within the wide realm over which Professor Thompson has presided for over twenty-five years, little has happened domestically to change the original structure and tactics of his book. For reasons usually unsuspected, morphologists have sterilized the analysis of finished form and are now concerned with incipient form or else browse in adjoining and temporarily more succulent pastures. While the progress made by morphological outpatients is reflected in the revisions, most of the amendments derive from the senior sciences or represent increments of learning and insight that have come to Sir D'Arcy from almost everywhere since 1917. In the aggregate these additions are massive. The list of topics, objects and personal names in the index has grown from roughly 1,464 to about 2,236. The footnotes alone would now make a unique compendium. Here ranging over the ages are quotations and references often unusual and usually neglected; numerous fragments of history otherwise inaccessible and sometimes shameful; excellent shop-talk and piquant asides. The absence of visible seams between the innovations and the old fabric is the more remarkable because of Sir D'Arcy's way of saying things. His style, still hampered only by the inhibitions of sound scholarship, flows easily and crystalline among biological, physical and mathematical rocks, yet modulated at will also expresses the intellectual serenity of a philosopher, the heat in the heart of a lover of knowledge and the deep feeling of a connoisseur of the good life. For sheer beauty it is difficult to match the Epilog with its significant and moving final tribute to the naturalist, Henri Fabre.

But what is the book about? Having lost none of its original virtues there is also no abatement in what many consider earmarks of original sin. Among living things form is a fact no less striking than among crystals. In both cases the materials out of which form fashions itself and the spaces within which the fashioning occurs have intrinsic properties antecedent to the form. These properties determine what form we shall finally see. But every living thing begins its independent existence with an endowment of ancestral genes. These also determine what the form shall be. This distinction between the properties which an organism has because it is part of this world at all and those which it has because its race has managed to survive, is not always easy to make but always easier to deny the closer a critic approaches the absolute zero of insight into physical science.

Sir D'Arcy Thompson can hardly be accused of being unbiological. Long intimate with living things, his constant reference tô the organism as an entirety,

[1] *On Growth and Form.* D'Arcy Wentworth Thompson. Illustrated. 1116 pp. $12.50. August, 1942. Cambridge: At the University Press; New York: The Macmillan Company.

his concern with relevant detail, and his insistence that intrinsic properties of component materials express themselves only under the restraints and constraints imposed by the organism all confirm his biological orthodoxy. What then is so heterodox?

Biologists adept at witchcraft of their own are often curiously subdued in the presence of real abstractions. Having separated the physically intrinsic from the physically but not biologically extrinsic, Sir D'Arcy reduces organic form to a diagram illustrating the combined play and interplay of all the forces operating at both physical and biological levels. Identical forms, whatever their size and no matter what the immediate circumstances of their origin, yield identical force diagrams. The consequences are often startling. The pattern of a chambered nautilus and the shell of a one-celled foraminiferan are both symptoms of underlying systems of energy whose visible expression in either case is the "Archimedean Spiral." The shape of a jellyfish and the head of a hydroid polyp are equilibrium figures akin to a permanent splash while the tetrahedral angle of spicules in sponges, corals and sea-cucumbers points to another type of physical uniformity in the generating force-field. Rarely as yet can the forces themselves be identified. Everything depends on the order of magnitude.

Sir D'Arcy devotes much of his space to the importance of mere size and exhibits the incongruities that follow when conclusions based on one order are transferred without change to a totally different order of magnitude. Thus when cilia become small whips their activity and even location tell little about the molecular forces that are effective and maintain in the one case an unstable and in the other a stable equilibrium. Once the far-reaching implications of this point are recognized in gross morphology, another mythological branch will crash at the foot of the phylogenetic tree.

With the recognition of size per se goes the analysis of changes in size. Though always absolute, their chief importance becomes apparent when they are relative. Every organism begins at the microscopic level; many become macroscopic, and practically all undergo complication through differences in local growth. Both absolute and relative growth are discussed in the chapter on growth rates, but with little indication that the "Thompsonian Transformations" of 1917 were the forerunners, and still remain, the hitch of heterogony. In his chapter on the Theory of Transformations Sir D'Arcy changes the relative values of units along conventional Cartesian axes and puts the methods of the cartoonist to scientific use. But amazing as it is, the transformation of a porcupine fish into a sunfish results in something more than fun. For "if in the evolution of a fish for instance, it be the case that its several and constituent parts, head, body and tail or this fin and that represent so many independent variants, then our coordinate system will at once become too complex to be intelligible . . . ". Indeed with anarchy in a normal organism so improbable Sir D'Arcy's method is sufficiently sensitive to detect whether a given bone or skull in a paleontological series of horses or men belongs to the stem we happen to be tracing or to some related side-line. Yet until some young paleontologist is prepared to bestow immortality on his critics, these transformations are likely to remain a red rag in the paleontological arena.

If the morphologist of the future is to go on at any of the levels where "Growth and Form" leaves off, he must undergo far more rigorous discipline in physics, chemistry and mathematics. Ultimately, Sir D'Arcy considers the mathematical requirement will exceed the competence of biologists. He envisages a day when all that is really important in biology must become the property of the most highly skilled of

physicists and mathematicians. Should this biological gloom materialize, physicists and mathematicians would need to become biologists and instead of dictating the terms under which they will work, must be prepared to accept dictation from the organism. A more likely alternative would seem to be team-work among scientists of all types. In the meantime what one biologist has accomplished single-handed should be a beacon light for all. Bring the distant future what it may, biologists working at the higher levels can best consolidate their gains and facilitate a real articulation of gross morphology with the newer results pouring in from the lower biological and molecular levels if they will make here and now wholehearted and concerted efforts to follow the trail blazed by D'Arcy Thompson's "On Growth and Form."

Otto Glaser

INTERPRETATION OF SCENERY[1]

In considering "Geomorphology" by von Engeln, the present reviewer is asking the question: to what extent is the layman able to use profitably an advanced college textbook in such a field of common interest as the interpretation of scenery? Regardless of the virtues of the book as a classroom guide, regardless of its richness of illustration and bibliography, will it answer adequately the kind of questions which may be asked by the earth-conscious traveler who is untrained in geology and geography? A biology teacher or a chemical engineer who enjoys travel may wonder how "things got that way" and hope for help from such a book. What, for instance and at random, about geysers in the Yellowstone, or what about the Devil's Tower, or, after a North Cape cruise, how about fiords? Obviously the book was not written for this purpose but, considered as a "Book on Science for Laymen," it is being evaluated with that possible virtue in mind.

Let us investigate the three topics mentioned above. A good impression comes from the index. It seems to be adequate, for all three items are included. Looking up geysers, we meet a little disappointment. Geysers are said to be not really pertinent to geomorphology. We do get some helpful information about how they obtain their heat though there is nothing to be found about the mechanism of intermittent eruption.

Devil's Tower (p. 307) appears to be all that remains of a dome-like igneous intrusion called a laccolith. There is a cross-section of a laccolith on the opposite page so we can discover what the term means, and a good picture of Devil's Tower on the next page so we can put diagram and reality together. However, we turn to the second reference (p. 609) and find that Devil's Tower is a volcanic neck, though there may be some dispute about it. We turn back a page to find out what a volcanic neck is and run into terms like "barrancas" and "planizes." Barrancas result when "originally numerous, subequal, consequent-stream furrows on the sides of a cone are in time replaced by a comparatively few deep and wide valleys." Eventually we find that a volcanic neck is one of the forms of "the inversion of relief that gives extraordinary prominence to a particular type of monadnock." At this point, as laymen, we are likely to turn back to the remnant-laccolith idea.

Now "fiord" (p. 468). Here we find that "sea-invaded basins, which commonly extend inland between nearly vertical walls, are *fiords.*" They were probably occupied in glacial times by tidal glaciers which ended seaward in great ice cliffs. So far, very good; then we try to follow the argument and we come on to "The depth of water in the part now evacuated is so great that the

[1] *Geomorphology. Systematic and Regional.* O. D. von Engeln. Illustrated. xxiv + 655 pp. $4.50. 1942. Macmillan Company.

above-water ice cliff would have been much higher than it was if the ice had been buoyed up at its terminus."

Although the topics were selected at random examples of the same kind might be multiplied. This reviewer's conclusion is that unless the layman is prepared to absorb a profuse terminology and unravel involved English he will not find the book helpful as a reference for the interpretation of scenery. At the present time it may be fortunate that many foreign terms like "wadi" are included. Ordinarily such nomenclature is of value only to the advanced student and professional.

If the layman is concerned with understanding the current state of one aspect of the earth sciences the volume can be said to reflect well the minds and attitudes of the more progressive geomorphologists. The presentation of the Penckian doctrines along with the traditional American, and the frequent reference to dissenting opinion are indicative of a broad scientific philosophy. And certainly no one can read a book and believe that any phase of the subject matter is static. Geomorphology, as with all branches of knowledge, is "unfinished business."

A. C. SWINNERTON

A STUDY OF BIRD PSYCHOLOGY[1]

THE work of the last decade or two on various aspects of bird behavior has changed our concepts of the "how" and "why" behind the activities of birds far more than has the descriptive or faunal work of the same period altered our ideas of bird classification and distributional history. The present book, which includes far more than its main title implies, is a welcome summary and critical digest of a great mass of recent work on birds in practically all parts of the world. The bibliography contains approximately 600 entries, and while some important behavioristic studies are omitted, the bulk of the more significant ones are included. While the vast literary material here assembled is introduced as needed into the text, the reader does not get the feeling of going through a mere series of excerpts and quotations. The author presents his own data and interpretations based on his personal experience plus the literature, which he calls in as evidence when needed.

Beginning with an account of the ceremonial activities of the gannet, Armstrong treats of such topics as the development of nest-building, courtship feeding (with amusing human parallels), ceremonial gaping, the "disablement reactions" involving injury—feigning and trance-like states and activities that reveal emotional states, and then goes on to discuss ceremonial behavior, both mutual and reciprocal, semi-solitary and social. This leads to a chapter on "The Dances of Birds and Men" followed by discussions of arena displays, the sex-ratio, territory, song and the display itself.

While supporting in large measure the interpretive suggestions and theories of Lorenz, the author is much impressed by Eliot Howard's semi-mystical, semi-philosophical analysis of the avian mind. Armstrong ends his brief account of the significance of display by reminding us that the bird's world is like a dynamic system of ever-changing relationships. "In the words of Hippocrates: 'Everything is in whole—part relationship, and, part by part, the parts in each part operate according to their function.' "

The book is not intended as easy reading, but is actually not only very readable, but by virtue of its condensed richness of data, an "easy-reading" of a large and scattered literature. Three indices, one to the species mentioned, one

[1] *Bird Display. An Introduction to the Study of Bird Psychology.* E. A. Armstrong. Illustrated. xvi + 381 pp. $5.50. December, 1942. The University Press, Cambridge, England (Macmillan).

to the topics, and one to the authors quoted, make the contents of this important book readily available to the interested reader.

HERBERT FRIEDMANN

A TRIP AMONG THE ISLANDS OF THE SOUTH PACIFIC[1]

A VOYAGE in a sixty-foot schooner through the Panama Canal and across the Pacific, with stops at the Galapagos, Marquesas, Tahiti, Samoa and Fiji, to Ontong Java, and then on to New Guinea, is in itself quite an excursion, but to the author of this book, merely the beginning.

During the voyage, observations were made of migratory birds and ocean life, but in New Guinea the real work of collecting ornithological specimens and observing bird life was begun. Fortunately, the Dutch Administrator, Mr. van der Goot, was about to make a patrol into the interior, and in his company the author made his first journey into the bush. Government rest houses, where they existed, were comfortable, but usually home was made in rickety houses in native villages where society consisted partly of rajahs, mostly of cannibals. In the mountains, sleeping in wool-lined bags, life was different from on the coast, where a rainproof cloth over one causes as great humidity inside as out. Van der Goot adapted himself to weather conditions by strolling through the rain smoking his pipe with the bowl upside down, and turning it right side up when the rain stopped.

[1] *Trail of the Money Bird.* Dillon Ripley. Illustrated. xii + 306 pp. $3.50. 1942. Harper and Brothers.

The author observed in New Guinea dances of birds of paradise, and the activities of the rare, New Guinea bower-bird. His native assistants collected and brought to him, among other things, small rails, together with the little houses bower-birds make of leaves to rest in during the night. Large collections were made, and many unusual and new notes on birds were obtained.

In addition to his ornithological work, Ripley experiences the usual hardships of travelers in the South Seas—bad weather, late Government parties, foot ulcers, leeches, and cold fried eggs for lunch.

After the big adventure of crossing the Pacific in a small boat, and a bigger one in New Guinea in territory new to collectors, there followed the voyage home, first in one of the comfortable Dutch passenger boats to Singapore, and then on a freighter, a forty-nine-day trip around the Cape of Good Hope, to Boston. None of the big steamers would take his cargo of eighty-seven live birds in forty-two cages.

Three adventure trips, all in one book, narrated in pleasant manner touched with humor, make this good reading on subjects of interest to everyone—the South Sea islands; natives, wild and tame; and bird life. The author draws a picture of a region that a few years ago was a collector's paradise, but even then conversations with settlers and Government officials regarding Japanese already there and others expected to come sounded an ominous note.

A series of interesting pictures adds to the enjoyment of the reader.

W. M. MANN

THE PROGRESS OF SCIENCE

THE NEW PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THOSE of us who belong to the large but favored group of Isaiah Bowman's old friends need a sharp reminder that "everybody" doesn't know him! There are, strange as it seems, thousands of fellows and members of the association who have yet to learn what manner of individual has just become the ninety-third president. Their curiosity, moreover, probably centers around questions of personality and traits rather than the impressive list of honors and responsibilities tersely set down in "American Men of Science," "Who's Who in America" and similar works of reference.

For the benefit of all such, let it first be noted that President Bowman is a very young man. The good die young, according to cynics, but the true explanation is not that they die *when* they are young but that they are young when they die. The inexorable record tells us that Bowman was born on the day after Christmas, 1878. Yet the characterization of a reporter who interviewed him in 1935, at the time he assumed the presidency of The Johns Hopkins University, applies with equal force to-day. It was: "Dr. Bowman is 57, looks 47, acts 37." Any one, indeed, who fails to deduct a round score of years from the new president's theoretical or chronological blood pressure and arterial elasticity will be bound to suffer an initial disadvantage.

It reveals no secret to state that Dr. Bowman has long been numbered among the annual candidates for the presidency of the association. One admirer, sending a letter of congratulation only last month, also offered to explain his election. "I have been voting for you for the last decade," he wrote, "and the Council has only just reached the point of counting all my ballots!"

Bowman is, and always has been, a geographer. No dictionary definition, however, encompasses the scope to which he has applied his chosen discipline. He has made his discoveries and wisdom bear not only upon the external world, but also with particular aptness upon sociology, history, government, international relations, the conservation of natural resources, and education (including that of his own children no less than of institutions). In short, he reveals "the pervading soul of the geographer that sees the basic bearing of the frame of the earth and the physical as well as social ties of its inhabitants."

Bowman received his bachelor's degree from Harvard in 1905. He still looked like a freshman, but he was considerably older than the average for his class because he had already completed the course in the State Normal College at Ypsilanti, Michigan. He then transferred to Yale, taking his doctorate in 1908 and remaining as instructor and assistant professor in the department of geography until 1915. In 1909, he married Miss Cora Olive Goldthwait, of Lynn, Massachusetts. Their two sons were born during the period of residence at New Haven and a daughter was added to the family shortly afterwards.

While at Yale, Bowman participated, either as staff geographer or as leader, in the several South American expeditions that opened opportunity to his penetrating insight and interpretive faculties, and led to the publication of one of his most delightful books, "The Andes of Southern Peru," and, later, to "Desert Trails of Atacama."

In 1915, he accepted the post of director of the American Geographical Society, New York City, after obtaining from the governing council assurances

DR. ISAIAH BOWMAN

that gave him a free hand for the productive developments of the next twenty years. The *Bulletin* of this oldest of American geographical organizations was replaced by the scholarly and more inclusive *Geographical Review,* and the society's headquarters rapidly became the center of cooperative work in geographic science, including cartography and the building up of a great library, which has won it a unique position as an essential adjunct, for example, to both peace-time and war-time activities of the United States Government.

In 1920, under Bowman's leadership, the society began the greatest single project ever undertaken by a geographic institution, namely, the preparation of a map of Latin America in conformity with the standards of the "Millionth-Map of the World" recommended by one of the International Geographical Congresses. This undertaking, now at the verge of fulfilment with all but three of the 107 sheets already issued, marks a new peak in excellence for the whole history of New World map-making.

As director of the American Geographical Society, Bowman first came conspicuously into the public eye by serving as an authoritative intermediary between geographic exploration and a general understanding thereof. No man has been more often or more properly sought by the press in connection with geographic news. His intimate relationship with its sources throughout the period of his directorship is indicated by the society's publications on the problems of the polar regions, its charts of the Arctic and Antarctic, and the practical aid it has given to Stefansson, Wilkins, Byrd, Ellsworth, Mawson and the Norwegian investigators of the Far South.

Nor was this advance on the physical frontiers sufficient. Opportunity for larger service in the cause of national welfare likewise appeared. In 1918, the building, staff and collections of the society were put at the disposal of the government for "The Inquiry" to prepare for peace, and Dr. Bowman himself acted as chief territorial adviser to the conference in Paris. No book has brought the society and the author more honor than "The New World," an outcome of these experiences in international affairs.

Bowman's influence stems, of course, not merely from his learning and character but equally from his power of concentration, his quick wit, and the clarity and directness of his speech. He is invariably "loaded for bear" when he opens his mouth, a fact that makes him a forceful protagonist and a dangerous adversary. The latter rôle is well illustrated by his routing of a cross-examining attorney in the famous Red River suit, relating to the boundary between Texas and Oklahoma, in which Bowman was engaged as physiographic expert to testify before a commissioner of the United States Supreme Court.

After drawing from Bowman a prediction as to a future position of the shifting channel of the Red River, the attorney seemingly lured the witness into the fatal commitment that he was quite willing to "prophesy." Somewhat to his surprise, the victim showed no hesitancy in accepting the bait.

"May I ask, then," continued the sardonic lawyer, "whether you regard yourself as a major, or merely a minor, prophet?"

"I am *called* a major prophet," responded Bowman.

His would-be tormenter paused, surveyed the court, and prepared for the kill. But his next question, demanding an explanation as to why an alleged man of science was willing to pose as a prophet, brought forth the riposte that devastated his whole attack and threw the court into a titter. It was only this: "I am called a major prophet, because my name is Isaiah."

We may skip, as information readily accessible elsewhere, the up-to-the-minute catalogue of Dr. Bowman's dozen or more books, six medals, thirteen honorary degrees, nine honorary fellowships in geographic societies, etc. Of his specific accomplishments at Hopkins, the writer is hardly qualified to speak. Neither is he able to distinguish between the president's personal share and that of his inspired colleagues with respect to notable and progressive changes. It is enough to say that wherever Bowman is, nothing stands still. The scholarship of Hopkins has won new laurels under his administration; its financial strength has measurably gained; it has become the first great university to eliminate gate receipts in connection with all athletic contests!

Our summary may be concluded somewhat randomly with a transliteration of a few of President Bowman's vigorous spoken sentiments applicable to questions of national and world-wide interest during the past several years.

Conservation: Americans have been willing to scalp their land and to leave it a red horror.—The waste of running water, and attendant evils, have done more damage to the United States than all its wars.—Man, so often extolled as a builder and beneficent modifier, has been equally a waster and disorganizer of the forces of nature.—Facts more valuable than all the gold of the Klondike lie buried in the climatological records at Washington.

Geography: The American frontier is gone, but the world, including our own country, is still filled with pioneer zones. —The "frozen north" has retreated northward faster than our school books have been revised.

Education: The fact that you are a university graduate may lull you into a false sense of intellectual attainment before you have really begun your life.—There is constant need of scholarship to effect a reconciliation between a society that molds and restricts and the individualism out of which the forces of society have so largely sprung.—Keep a healthy distrust of "common sense," such as once told men the world was flat.—Neither scientist nor government can work on a hunch.

Freedom: Freedom to think, to discover and to report is more important than either government or society itself, for it was out of that freedom, or its winning, that there came ultimately the builders of our civilization.—Beware the false design of citizenship which asserts, "I am a child of the government and heir of my neighbors' industry and prudence."

ROBERT CUSHMAN MURPHY

ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE eightieth annual meeting of the National Academy of Sciences was held on April 26 and 27, 1943, at the Academy building in Washington; it was attended by 114 members. No scientific papers were read at the meetings; the greater part of the sessions the first day was devoted to general statements of the various investigations undertaken by the Academy at the request of the government. President Jewett opened the discussion with a paper on the "National Academy of Sciences and Its Part in the War—the Academy in Relation to the Government," in which he emphasized the responsibility of the Academy toward the government in the field of science and its applications. Descriptions of various phases of this responsibility and of the steps that are being taken to meet it were given in the following papers:

VANNEVAR BUSH.—The Office of Scientific Research and Development and its relation to the Academy in the war. JAMES B. CONANT.—The National Defense Research Committee in its relation to the Academy during the war. A. N.

RICHARDS.—The National Academy of Sciences and the Committee on Medical Research of the Office of Scientific Research and Development. ROSS G. HARRISON.—The National Research Council and the war effort. CLYDE WILLIAMS (by invitation).—Essential metals and minerals for war purposes (informal discussion by Drs. C. K. Leith and Zay Jeffries). W. F. DURAND.—Application of engineering science in war. LEWIS H. WEED (by invitation).—The role of medicine in the present war. LEONARD CARMICHAEL (by invitation).—Psychology and the war. FRANK G. BOUDREAU (by invitation).—Food and nutrition in war and peace. Program of the Food and Nutrition Board.

Five medals, awarded by the Academy, were presented at the annual dinner on Monday evening, April 26, 1943:

The Henry Draper Gold Medal, awarded to Dr. Ira Sprague Bowen, of California Institute of Technology, Pasadena, California, "in recognition of his contributions to astronomical physics; more especially his researches on the spectra and chemical composition of the gaseous nebulae." The presentation address was made by Dr. S. A. Mitchell, of the Leander McCormick Observatory.

The Alexander Agassiz Gold Medal and honorarium of $300, awarded to Dr. Columbus O'Donnell Iselin II "for his studies of the gulf stream system, for his leadership in the development of a general program of the physical oceanography of the North Atlantic, and for his distinguished direction of the activities of the Woods Hole Oceanographic Institution both in peace and in time of war." The medalist was presented by Dr. Thomas Barbour, of the Museum of Comparative Zoology, Cambridge, Massachusetts.

The Daniel Giraud Elliot Medal and honorarium of $200, for the year 1935, awarded to Dr. Edwin H. Colbert, of the American Museum of Natural History, "in recognition of the high merits of the paper entitled, 'Siwalik Mammals in the American Museum of Natural History' published in the Transactions of the American Philosophical Society in 1935." The medalist was presented by Dr. W. K. Gregory, of the American Museum of Natural History in New York City.

The Daniel Giraud Elliot Medal and honoramium of $200 for the year 1936, awarded to Dr. Robert Cushman Murphy, of the American Museum of Natural History, "in recognition of the high merits of his work on 'Oceanic Birds of South America' published in two volumes in 1936." The presentation speech



Left to right: Dr. A. Adrian Albert, professor of mathematics, The University of Chicago; Dr. C. G. Rossby, professor of meteorology, The University of Chicago; Dr. J. W. Beams, professor of physics, University of Virginia.

TOP: *left to right:* Dr. Lee A. DuBridge, professor of physics, University of Rochester; Dr. Paul D. Foote, vice president, Gulf Research and Development Company; Dr. V. K. Zworykin, director, Electronic Research Laboratory, RCA Manufacturing Company. MIDDLE: L. H. Adams, director, Geophysical Laboratory, Carnegie Institution of Washington; Dr. L. P. Hammett, professor of chemistry, Columbia University; Dr. Walter P. Kelley, professor of agricultural chemistry, University of California, Citrus Experiment Station. BOTTOM: Dr. L. Michaelis, member, Rockefeller Institute for Medical Research; Dr. A. F. Buddington, professor of geology, Princeton University; Dr. H. B. Vickery, biochemist, Connecticut Agricultural Experiment Station.

TOP *left to right* Dr. C. V. Taylor, Herzstein professor of biology, Stanford University, Dr W. H. Chandler, professor of pomology, University of California at Los Angeles; Dr. J. N. Couch, professor of botany, University of North Carolina. MIDDLE Dr. Leonard Carmichael, president of Tufts College; Dr. Calvin P. Stone, professor of psychology, Stanford University; Dr. Wallace O. Fenn, professor of physiology, University of Rochester. BOTTOM: Dr Warfield T. Longcope, professor of medicine, Johns Hopkins University School of Medicine; Dr. E. K. Marshall, Jr., professor of pharmacology and experimental therapeutics, Johns Hopkins University School of Medicine; Dr. O. H. Robertson, professor of medicine, The University of Chicago.

was made by Dr. Ross G. Harrison, of Yale University.

The John J. Carty Medal and award for the Advancement of Science, for which the honorarium is $4,000, awarded to Dr. Edwin Grant Conklin, of Princeton University. The citation read: "Zoologist, Cytologist, and Embryologist; Philosopher, Teacher, and Scientist; Student of life and of growth from lowliest beginnings to highest consummation." The medalist was presented by Dr. O. E. Buckley, of the Bell Telephone Laboratories. In accepting the honor Dr. Conklin expressed his pleasure and appreciation of the award and his surprise that he had been selected for it. He recalled his long friendship with General Carty, in whose honor the John J. Carty fund was established, and expressed great satisfaction in being thus associated with one whom he had greatly admired and respected.

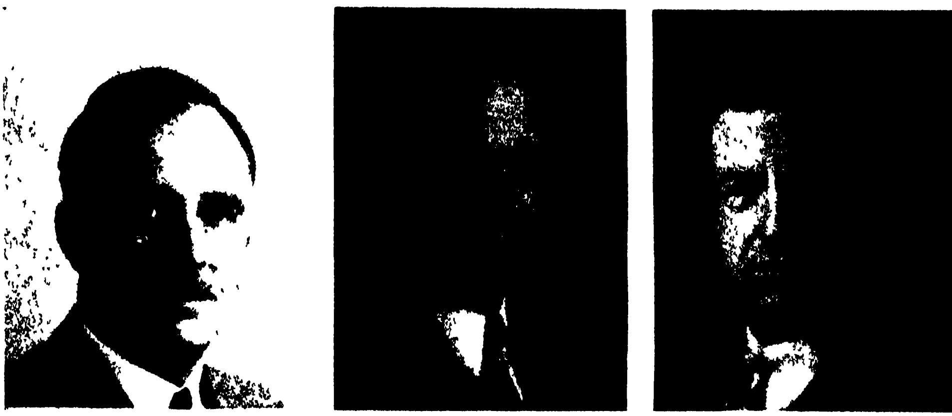
At the business meeting held on Tuesday, April 27, the following officers and foreign associates were elected:

President—Frank B. Jewett, Bell Telephone Laboratories; reelected for a term of four years.

Home Secretary—F. E. Wright, Carnegie Institution of Washington; reelected for a term of four years.

Members of the Council (terms of three years).—W. Mansfield Clark, Johns Hopkins Medical School (reelected); Walter R. Miles, Yale University School of Medicine.

Foreign Associates.—Alfonso Caso, archeologist, Instutio Nacional de Antropologia e Historia, Mexico. Harold Spencer Jones, astronomer, Royal Observatory, Greenwich. Richard Vynne Southwell, engineer, Brasenose College, Oxford University. Charles Edward Spearman, psychologist, University of London. Sir D'Arcy Wentworth Thompson, zoologist, University of St. Andrews. Hendrik Johannes van Der Bijl, engineer, University of Pretoria, Pretoria, Union of South Africa.



TOP: *left to right:* Dr. W. Albert Noyes, Jr., professor of physical chemistry, University of Rochester; Th. Dobzhansky, professor of genetics, Columbia University; L. C. Dunn, professor of zoology, Columbia University.

Twenty-six scientists were elected members of the Academy, whose portraits, with the exception of those of Dr. E. J. Cohn, professor of biochemistry at Harvard Medical School, and Dr. William V. Houston, professor of physics at California Institute of Technology, appear on these pages. The present membership of the Academy is 345, with a membership limit of 450; the number of foreign associates is thirty-nine with a limit of fifty.

The autumn meeting will be held this year in Washington, at a date to be selected.

F. E. WRIGHT,
Home Secretary

FRANKLIN MEDALISTS FOR 1943

Two eminent American scientists have been chosen to receive the coveted Franklin Medals, which were presented at the annual Medal Day ceremonies at The Franklin Institute, Philadelphia, on April 21.

George Washington Pierce, who formerly held the chairs of Rumford professor of physics and Gordon McKay professor of communication engineering at Harvard University, has been chosen "in recognition of his outstanding inventions, his theoretical and experimental contributions in the field of electric communication, and his inspiring influence as a great teacher."

Professor Pierce is the author of thirty or forty valuable papers in physics and electric communications, and is the author of two standard books, "Principles of Wireless Telegraphy" (1910) and "Electric Oscillations and Electric Waves" (1920).

Following the discovery of the crystal detector, radio made rapid strides. The crystal detector consists of a material, such as carborundum, against which a metallic contact is held under light pressure. This device possesses the property of conducting current better in one direction than in the other, and the detector action is due to this property. Realizing the importance of the discovery, Pierce began a series of systematic investigations to find what other materials possessed the same rectifying properties, and also to discover to what this property is due. As a result of his investigations, Pierce found a number of minerals which could be used as detectors. He applied the cathode-ray oscillograph to the study of the action and found that neither an electrolytic theory nor a thermo-electric theory could explain the rectifying phenomenon. It is noteworthy that additional investigations have failed to provide a satisfactory explanation of the basic rectification phenomenon in crystal detectors.

His interest in the detection of electric oscillations led Pierce to experiment with mercury vapor arcs for this purpose. The outcome of his researches was the mercury vapor detector and amplifier. This tube is equivalent to the "Thyratron," developed later by A. W. Hull, of the General Electric Research Laboratories. The chief difference between Pierce's tube of 1913 and the present day thyratron is the use in the latter of a hot cathode as a source of electrons instead of the mercury tube and "keep-alive" circuit employed by Pierce. However, he employed his tube as an amplifier as well as a detector. In one of his patents he discloses a method of using it in a way which is equivalent to the present use of the mercury tube employed to record variable-density sound-on-film.

During the last World War, Pierce gave his full time services to the United States Navy at the Naval Experimental Station, New London, Conn. Together with other well-known physicists, he was engaged upon diversified research related to the creation of devices for locating submerged submarines. His work touched practically every aspect of the manifold problems arising from this enterprise. His profound knowledge of theoretical and practical physics, and his ability to design workable equipment were a source of constant amazement to his associates. Probably his most important personal contribution to the work was the electrical compensator. This ingenious device was the electrical analogue to Dr. Mason's multiple-unit acoustical listening device, the MV tube.

The electrical compensator contained a multiplicity of electrical lag lines which were invented by Pierce. These were formed of repeated sections, each consisting of a series inductive element and a shunt capacitive in the higher audible or ultra-audible range. He was the first to demonstrate that such lines had the property of retarding electrical

impulses by time intervals which were equal to the square root of the product of inductance and capacitance of the individual sections, and that the correct amount of mutual inductance between adjacent sections was beneficial to the transmission characteristics of the line.

Cady pointed out in 1922 that the piezo-electric effect in quartz crystals could be used to control the frequency of electrical vacuum tube oscillators. By virtue of the extremely low internal viscosity and the small effect of temperature such crystal resonators are extremely stable and permit control of the frequency of oscillators to a few parts in ten millions under proper conditions. Much impressed with Cady's work, Pierce began the study of suitable oscillator circuits for use with quartz crystals. He produced three fundamental types of circuit employing one tube and one set of electrodes on the crystal. Cady had previously employed two tubes and two sets of electrodes, so that Pierce's circuits were a considerable simplification.

This joint invention by Cady and Pierce is one of the most important inventions made in radio during the past twenty years. Because of the necessity of holding frequencies to narrow limits all broadcasting stations are required by law to employ quartz crystal stabilization. Another important use is in electric clocks and in frequency standards. The quartz crystal clock is probably the most accurate time-keeper ever devised.

When a bar of iron or nickel is magnetized it changes shape due to the effect called "magnetostriction." Also, when a bar of iron is deformed it generates a magnetic moment by a converse effect. These two effects may be compared to the direct and converse piezo-electric effects in a quartz crystal, which has just been described. Pierce recognized that the phenomenon of magnetostriction could be used to control the frequency of oscillators by mechanical resonance in the same way as with quartz crystals. Near the frequency of mechanical resonance bars of proper composition exhibit a considerable reaction on the electric impedance of a coil wound around them. Pierce devised a number of oscillator circuits for making use of this property.

THE FRANKLIN MEDAL

Professor Pierce's influence has been impressed widely upon the field of electric communication, for the majority of the men who are engaged upon important work in radio engineering all over the world have studied in his classes. His courses in wireless telegraphy were among the first to be given anywhere,

DR. G. W. PIERCE

and for years were a standard on which other schools based the development of their curricula. Pierce recognized that the art of communication was neither physics nor engineering, but a combination of the two. He always insisted upon a liberal grounding in mathematics and usually left the engineering part to be developed by the student himself as he went along.

The other Franklin Medalist is also a native-born American. Dr. Harold Clayton Urey was born in Walkerton, Indiana. Graduating from the University of Montana with the degree of bachelor of science in zoology, Dr. Urey concentrated on chemistry when he received an appointment in the laboratory of the Barrett Company in Philadelphia. Later he spent a fruitful year in the laboratory of Nils Bohr at Copenhagen. Upon his return to the United States he went to Johns Hopkins University as associate in chemistry, from which he went to Columbia University where he eventually became professor of chemistry.

During the past dozen years, Dr. Urey has written more than sixty papers for technical journals and is co-author with

DR. HAROLD C. UREY

Professor Ruark of the book "Atoms, Molecules, and Quanta." He has been editor of the *Journal of Chemical Physics* since its inception.

Dr. Urey has been the recipient of the Willard Gibbs Medal from the American Chemical Society, the Davy Medal from the Royal Society and the Nobel Prize in Chemistry. The award of the Franklin Medal is in recognition of "his discovery of an isotope of Hydrogen of mass 2, which has resulted in the opening of new fields of knowledge in three of the physical sciences."

The atomic weight of an element is usually found as the result of some chemical procedure in which the mass of a given volume of the unknown element is compared with the mass of the same volume of oxygen, assumed to have an atomic weight of 16.0000. Many millions of atoms of the unknown element, as well as many millions of atoms of oxygen, participate in such an experiment. Unless all the atoms of oxygen have identical mass, and all the atoms of the unknown element also have identical mass, the atomic weight so found represents only the average atomic weight of the group. In the case of hydrogen the atomic weight thus found has the value of 1.00777.

With the discovery of the mass spectrograph by F. W. Aston it became possible to calculate the atomic weight of particles appearing upon a spot on a photographic plate. Particles of different atomic weight were focussed upon different spots on the plate. Aston found by his method that the atomic weight of hydrogen is 1.00778. However, it was later found that normal oxygen is a mixture of 0(16) with small amount of 0(18) and 0(16). Therefore, if we take the atomic weight of 0(16) as 16.0000 it is clear that the atomic weight of oxygen as found by the chemists must be slightly higher than 16.0000 due to the presence of the heavier isotope. Since the atomic weight of hydrogen is established by comparison with that of oxygen, the inference is that the atomic weight of hydrogen should be higher than 1.00777.

Birge and Mentzel pointed out that the higher value for hydrogen might be explained by postulating the existence of one or more heavier isotopes of hydrogen. They estimated that if there existed a single isotope of atomic weight approximately 2, there would be need for only one atom of H(2) to 4500 atoms of H(1) in order to account for the discrepancy. In 1931 it was not possible to detect an isotope of such infrequent occurrence.

At this point Dr. Urey attacked the problem. He realized that, in order to establish the existence of H(2), two things were required: (a) he must find a method of concentrating the heavier isotope in a sample of hydrogen so as to increase the frequency of its occurrence, and (b) he must find a more sensitive method of detecting the presence of the heavier isotopes than that provided by the mass spectrograph.

From the thermodynamic theory he deduced that liquid H(2), deuterium, should have a somewhat higher boiling point than liquid H(1), protium. Hence, he turned to fractional distillation as the means of concentrating deuterium by boiling off the protium. Since it was clear that the difference between the two boiling points must be small, he had to work as closely as possible to the known boiling point of hydrogen. We now know that the boiling point of protium is 20.4° Abs. and the boiling point of deuterium is 23.5° Abs. In one experiment he started with six liters of hydrogen and boiled it away until there was left only one cubic centimeter.

For a more sensitive method of detection Urey turned to the spectroscope. Bohr's theory of the hydrogen spectrum had been successful in deriving a relationship between known physical constants and Rydberg's number, familiar to all spectroscopists. This theory is based upon the assumption that an atom of hydrogen consists of a single proton which remains motionless while an electron revolves about it. In reality, the proton and the electron must both revolve about a common axis which does not pass through the center of the proton, just like the earth and the moon.

If we now postulate the existence of deuterium, Bohr's theory leads us to suppose that a deuterium atom possesses a structure similar to that of a protium atom in having a single orbital electron but different in having a nucleus of about twice the mass. Hence, Rydberg's number for deuterium should be a little larger than that for protium.

In order to make use of a high-powered spectrometer and also to carry out the work of liquefying large quantities of hydrogen, Urey and his assistant, Murphey, went to the Bureau of Standards, and enlisted the aid of Dr. Brickwedde. They set up a spectrometer using a concave diffraction grating of 21-foot focus with a dispersion of 1.3 A per millimeter, and photographed the spectrum obtained from an electric discharge in a tube containing hydrogen. Three samples of this gas were investigated: ordinary hydrogen, hydrogen en-

riched by boiling at atmospheric pressure, and hydrogen enriched by boiling at a temperature just above the triple point.

The first photograph showed the strong H line accompanied by a very faint line on the short wavelength side, which might or might not be a ghost line. The second photograph showed the companion line in the same location but of increased intensity. In the third photograph the intensity of the companion line was much greater, leaving no doubt as to the true nature of this line. The separation was measured as 1.313 A, very close to the calculated value of 1.326 A. Other lines in the spectrum were found to be accompanied by a companion on the short wavelength side.

Since deuterium promised to be such a useful substance, if only it could be obtained more readily, Urey set to work to devise a better method of enrichment than fractional distillation. By the use of fractional electrolysis he was able to obtain a residue containing as high as 90 per cent. heavy atoms.

The discovery of deuterium has proved to be one of fundamental importance in the fields of chemistry, physics, and biology. A new chemistry has been born in which every compound containing hydrogen is found to acquire changed properties when deuterium is substituted for protium. In the field of nuclear physics, deuterium has proved of inestimable value because of its use as a projectile accelerated to terrific speeds in an atom-smashing machine. When the electron has been knocked off an atom of deuterium there remains only the positively charged nucleus, or deuteron, which is twice as heavy as the nucleus of protium, or proton. In the atom smasher the deuterons acquire high speed and comparatively great kinetic energy which enables them to penetrate into the very hearts of much heavier atoms against which they are shot. The result is that these heavier nuclei are frequently smashed to pieces, giving rise to new nuclei, which means that new atoms with new properties have been artificially created, a process of actual artificial transmutation of elements.

The use of deuterium in biological work is interesting if not as important, at present, as in chemistry and physics. Tadpoles are killed when required to live in 92 per cent. heavy water. A mouse which has been deprived of water overnight showed marked signs of intoxication when fed heavy water. The more of it he drank the thirstier he became, so that it is probable that heavy water is not eliminated so readily from the human body as ordinary water. It is suggested that the proportion of heavy water in the body slowly increases, and thus, perhaps, brings on old age.

The contributions of these two distinguished scientists justifies their inclusion in the increasing list of Franklin Medal winners, which already includes such names as Einstein, Curie, Marconi, Planck, Thomson and Rutherford.

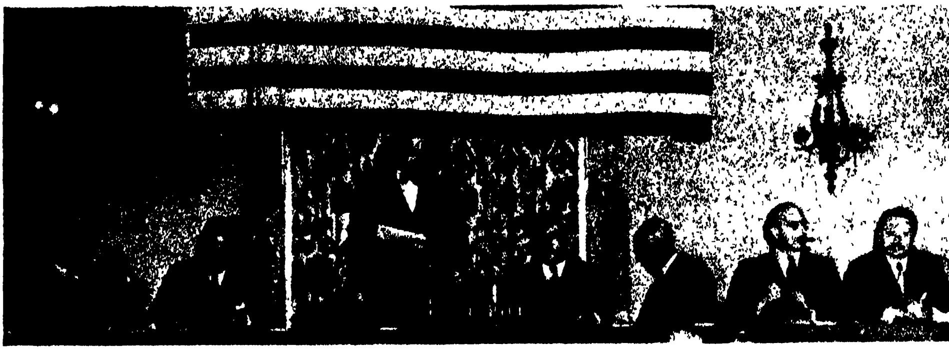
HENRY BUTLER ALLEN

A WARTIME CONFERENCE

THE need for the full mobilization of the trained personnel in support of the war effort was the theme of the "National Wartime Conference" held in New York City in May. It was sponsored by the American Association of Scientific Workers, and the United Office and Professional Workers of America, which is a branch of the Congress of Industrial Organizations[1] and twenty-one other organizations.

The general session was followed by

[1] Dr. Kirtley Mather, professor of geology at Harvard University and President of the American Association of Scientific Workers, served as conference chairman. The presiding officers and their panels on science were: Otis W. Caldwell, "Science and Technology"; John P. Peters, "Health and Welfare."



PRINCIPAL SPEAKERS IN THE "SCIENCE PANEL"

LEFT TO RIGHT: SENATOR HARLEY M. KILGORE; FREDERICK L. HOVDE OF THE NATIONAL DEFENSE RESEARCH COUNCIL; DR. THEODOR ROSEBURY, CHAIRMAN OF THE NEW YORK BRANCH OF THE AMERICAN ASSOCIATION OF SCIENTIFIC WORKERS; DR. ALBERT B. NEWMAN, REGIONAL ADVISER OF THE ENGINEERING SCIENCE MANAGEMENT WAR TRAINING; DR. OTIS W. CALDWELL, EMERITUS PROFESSOR OF EDUCATION, TEACHERS COLLEGE, COLUMBIA UNIVERSITY; DR. A. KENNETH GRAHAM OF THE WAR PRODUCTION BOARD; LEWIS A. BERNE, PRESIDENT OF THE FEDERATION OF ARCHITECTS, ENGINEERS, CHEMISTS AND TECHNICIANS OF THE CONGRESS OF INDUSTRIAL ORGANIZATIONS

simultaneous panels on science and technology, health and welfare services, education, white collar fields, and the arts and letters, each of which discussed three themes: the group's contribution to the war and to the peace, obstacles to the fullest participation in the war effort, and suggestions for overcoming them.

The science and technology panel emphasized the need for scientists and for effective organization and integration of scientific work. Mr. Frederick Hovde and Dr. Kenneth Graham described the work done by the Office of Scientific Research and Development and the Office of Production Research and Development of the War Production Board.

Defective allocation of manpower contributes to a growing shortage of trained personnel, Dean Albert B. Newman, of the Engineering School of the City College of New York, emphasized. He warned that the nation faces an acute shortage of adequately trained engineers. He said that the colleges will be able to supply only 10,000 of the 40,000 additional engineers needed in 1943. Industry contributes to this shortage by failing to request deferment for trained men. Financial considerations and general public approval for a college "which goes 100 per cent. military" are moving many college administrators to "dismiss all civilian students and fill up with Army and Navy trainees"; the training given them is inadequate for the demands of industry. Senator Harley M. Kilgore, sponsor of the current "Science Mobilization Bill," expressed the opinion that the "Scientific Roster" had not been used adequately. Dr. Theodor Rosebury pointed to the store of skills of scientific personnel which he thought had not yet been brought into war activity. The same point was stressed by Mr. Berne.

The speakers urged that the cooperation of scientists with other professions and groups be continued; they agreed with Dr. Mather, who stated, "This is the first time that representatives of all the professions have met together to consider their place in the wide perspective of national life. . . . Our common bond is our love of freedom."

ALEX B. NOVIKOFF

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